The Regulation of Alternating-Current Generators

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The Regulation of Alternating-Current Generators.*

BY PROF. C. L. CORY.

The following paper is not a theoretical one, notwithstanding the fact that the theory of lagging and leading currents must be for a moment discussed before the results of the tests and experimental work are considered. The practical bearing of the regulation of alternating-current generators is of great importance to all of us who have to do with the operation of transmission plants.

Figure 1 shows a circuit containing only resistance, the entire resistance being 40 ohms. The electromotive force is 1000 volts, the current 25 amperes. The power in watts is represented by the product of 1000 volts and 25 amperes, or 25,000 watts. The product of the resistance and the current squared, or 40 ohms multiplied by 25^2 is similarly 25,000 watts. Reference to the figure will show that the power curve is entirely above the neutral line, and at all times is represented by the product of the current and electromotive force.

Figure 2 shows the same alternator connected to the circuit containing 40 ohms resistance and a self-induction of $\frac{1}{10}$ of a henry. If the frequency of the alternator is approximately 48, this self-induction produces a reactance of 30 ohms. This self-induction in the circuit reduces the current to 20 amperes and the apparent watts will be 1000 volts multiplied by 20 amperes, or 20,000 watts. The real power in watts, however, is the product of the current squared and the resistance, or 16,000 watts. The power factor then, is the real watts divided by the apparent watts, or 0.8.

Referring to the curves of electromotive force, current and power, it is noted that the current is zero when the electromotive force has a positive value. The angle of lag in this case is 32 degrees and 52 minutes. We note then, that the current is reduced, due to the added self-induction, and the power is also less. It should be remembered that the self-induction absorbs no energy. On this figure it can be observed that the current curve may be broken up into two other curves. The power current, or current which is in phase with the electromotive force and the reactive current, or current which lags 90 degrees behind the electromotive force. The power current is 16 amperes and the reactive current 12 amperes.

If we replace the self-induction by a condenser, the capacity of which is 111 micro-farads, we have a condition of a circuit containing resistance and capacity. The curves are shown in Figure 3. If the frequency is again approximately 48, we have 40 ohms resistance and 30 ohms reactance. The apparent watts will be represented by the product of 1000 volts and 20 amperes, or 20,000 watts. The real watts will be represented by the product of the 40 ohms resistance and the 20 amperes squared, or 16,000 watts. The power factor, which is again the real watts divided by the apparent watts, is 0.8. The figure shows the curves of electromotive force, current and power. Lagging currents then are caused by a self-induction in the circuit, while capacity causes a leading current. In either case we have chosen, if we combine the 30 ohms reactance to the 40 ohms resistance, we find the result is 50, and we can say the *impedance* of the circuit is 50 ohms.

Figures 5, 6, and 7 show the curves taken from a constant-potential, direct-current multipolar generator. Figure 8 shows the relation between the drop in the armature due to resistance alone, and the drop due to the impedance of the armature. These were taken from the 30-kilowatt single-phase alternator. Figure 9 is the magnetization curve, ascending and descending, taken from the ⅓-kilowatt two-phase alternator. Figures 10 and 11 are the regulation curves, taken from the same machine. In taking the curves shown in Figure 7 it was impossible to maintain a constant power factor, but the similarity of the curve taken with unity power factor and with the power factor varying from 0.6 to 0.9 is clearly shown.

Figure 12 shows the magnetization curves of the one-horse-power C.-W. motor-alternator. Figure 13 shows the regulation curves of this same machine. Figures 14, 15, 16 and 17 are the curves taken from the 30-kilowatt single-phase alternator. Figure 18 is the curve showing the relation between the demagnetizing effect and the power factor. Figure 19 shows a cross-section of the armature core of the 30-kilowatt single-phase alternator. Figures 20 and 21 represent graphically the 10-mile, 10,000-volt (at receiving end), 500-kilowatt (at receiving end), single-phase transmission system. The frequency is taken at 60 cycles; the line a pair of No. 1 B. & S. copper conductors strung 18 inches between centers. In Figure 20 the load is non-inductive, or the ordinary lighting load, giving a power factor of .99. In Figure 21 the load is inductive, giving a power factor of 0.8.

THE electromotive force produced in any given dynamo is directly proportional to three factors: the speed, or the number of revolutions per minute; the number and arrangement of conductors on the armature; and, the strength of the magnetic field in the space through which the conductors are moved. As is well known, the conductors in which the electromotive force is produced are sometimes stationary, in which case the magnetic field is caused to move or to change in strength, which is equivalent in every way to the movement of the conductors when the magnetic field is stationary. As long as these three factors are constant, the electromotive force generated in the coils of an armature is constant.

Let us first distinguish clearly between the two expressions, "the electromotive force," and "the difference in potential" (or "voltage") "at the terminals of the machine." The electromotive force is the entire

*A paper read before the Third Annual Convention of the Pacific Coast Electric Transmission Association, San Francisco, June 20-21, 1899.

electrical pressure produced. The difference of potential at the terminals, or the voltage at the commutator or collecting rings, is less, on account of the drop in pressure through the armature, and, in some machines, also the drop in pressure in series turns. In direct current constant potential machines, this drop is equal to the product of the resistance, in ohms, of the armature, and perhaps of the series coils, multiplied by the current through the armature.

In alternating current generators, this drop is equal to the impedence of the armature, multiplied by the current through the armature. It is evident, therefore,

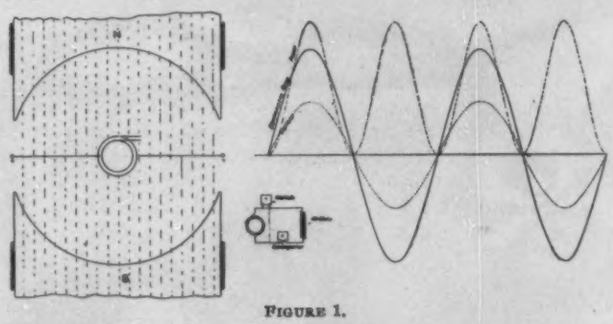

FIGURE 1.

that this drop in pressure in the armature, in alternating current generators is not alone dependent upon the ohmic resistance, but also upon the inductance or self-induction of the armature as well.

Therefore let us understand this distinction: a constant potential generator is one which gives us a constant difference of potential at the terminals of the machine, or collecting rings; the entire electromotive force generated by the armature being of practically no importance, whether it is constant or not. By this

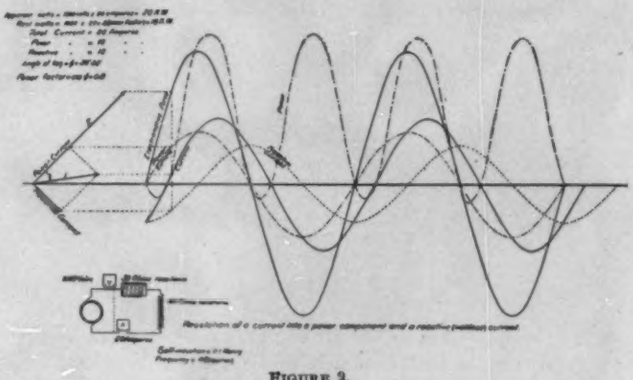

FIGURE 2.

constant potential at the collecting rings, it is understood that it refers to all loads, from no load to full load; and not only that, but the load is to be of any character. And in alternating current machines the load may be either such that the power factor is unity or the power factor less than unity.

Considering the three factors, the speed, the number of armature conductors, and the strength of field, let us take them up in order.

Practically, it is of course best to have the speed constant at all loads. We know how difficult this matter is where electrical energy is generated from water power. Water-wheel governors have what may be called a time element; that is, if given time enough, they will bring the speed up to its original value after it has suffered a reduction by increased load. The very

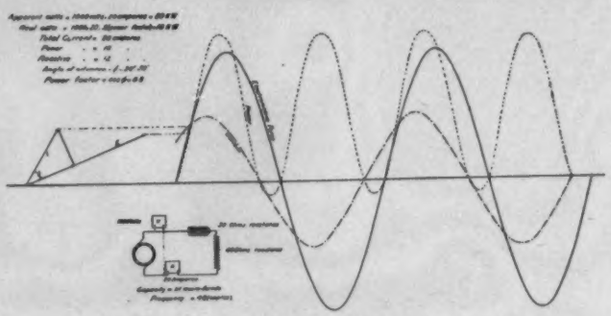

FIGURE 3.

sudden fluctuation of load, lasting but a few seconds, is where the water-wheel governor has its hardest, and, in some respects, its most important work to do.

Steam-driven generators usually have an almost constant speed at all loads. The character of mechanical power used to drive alternating current generators, it is very evident, has nothing to do with the inherent regulation of the generator itself; and we are to concern ourselves, for the present, only with the generator.

Considering the number and arrangement of conductors on the armature, it need only be said that, with one or two notable exceptions, it is not possible, practically, to change the number of conductors on the armature while the machine is in operation. Where the armature coils are stationary, this change in the number of armature conductors is possible, and is, as is well known, effected in some types of alternating current generators, both single-phase and polyphase. Generally speaking, however, this is possible only with particular types, and hence, while of great importance, is not possible of application in general.

Considering the strength of the magnetic field through which the conductors are moved, we find two

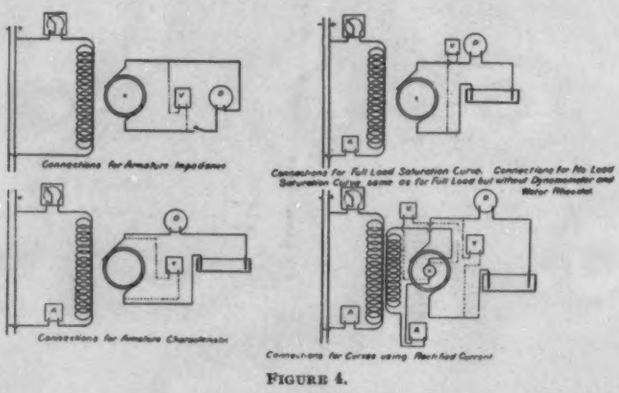

FIGURE 4.

effects: one is the effect of the ampere turns on the field, an increase of which tends to increase the strength of the magnetic field; the other, the ampere turns of the armature, an increase of which tends to diminish the strength of the magnetic field.

This demagnetizing effect of the armature current is of very much greater importance in direct-current machines than in alternating-current machines, providing we speak of alternating machines which are used principally for incandescent lighting—that is, where the power factor is very nearly unity. At one time it was thought impossible to reduce the air gap for the direct-current potential generator below a certain minimum value, inasmuch as a large air gap naturally tends to diminish the demgnetizing effect of the armature cur-

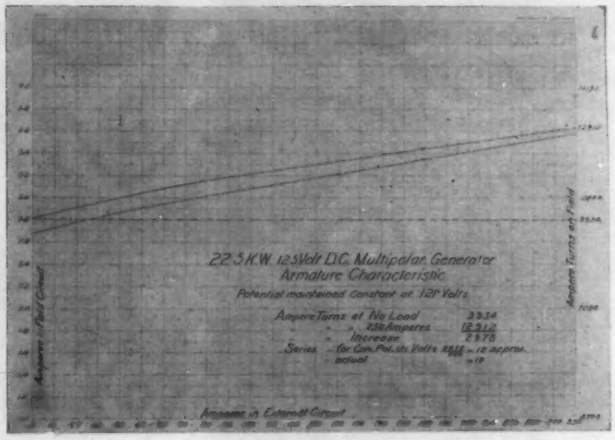
22.5 K.W. 125 Volt D.C. Multipolar Generator
Armature Characteristic
Potential maintained Constant at 125 Volts
Amperes in External Circuit

FIGURE 5.

rent in such machines. At the present time this tendency, which always results in a reduction of the electromotive force of a machine, is counteracted in two ways: 1st, by the use of compound winding; and secondly, by making the number of ampere turns on the field very large as compared with the number of ampere turns on the armature.

In discussing the regulation of alternating-current generators, I intend to confine myself to two of the effects mentioned above—first, the drop through the

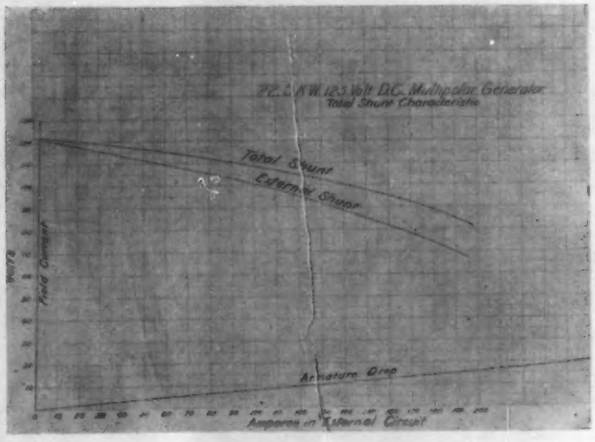

FIGURE 6.

armature, and second, the change in the strength of the magnetic field due to the demagnetizing action of the armature current.

Taking up the first question, of the drop through the armature, as applied particularly to alternating-current generators: As has been said above, it is evident that the loss of pressure in the armature is not alone due to the resistance of the armature, but also to the self-induction of the armature. The self-induction of the armature depends largely upon the character of the

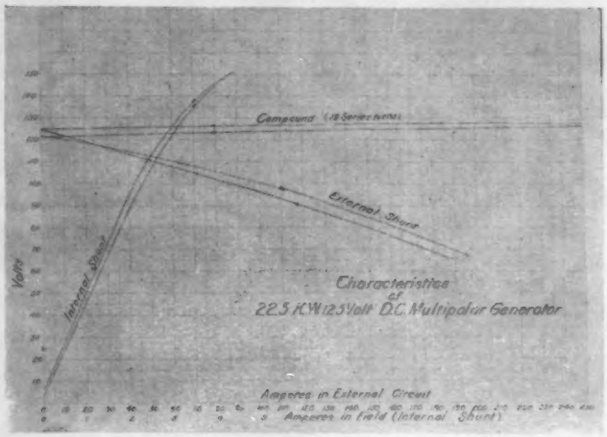

FIGURE 7.

armature winding. The self-induction of the armature may be said to depend, approximately, in such cases, as follows: It is proportional to the square of the number of turns in one armature coil, proportional to the area of that coil, and proportional to the permeability or magnetic quality of the material inside and surrounding the coil.

The three types of armature winding that are used in practical work are, the smooth core (the so-called "pancake" coil armature), the slotted armature (such as is largely used at the present time for many constant potential direct-current generators, as well as for constant potential alternating-current generators), and the "unitooth" armature (where the coils are wound upon the armature teeth, the number of coils being comparatively small, and, in the particular machine experimented upon, equal to the number of pole pieces).

With a given number of conductors on an armature, if the coils are of small number, the number of conductors per coil must be large; so that, as might be supposed, the self-induction of an armature so wound

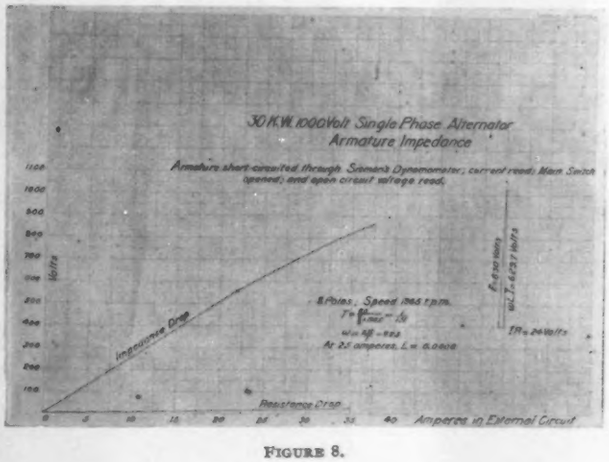

FIGURE 8.

is usually very high—due to the fact that there are a large number of turns in the coil, and that these coils are wound upon a large iron tooth of the armature.

Again, the self-induction of the armatures of the original alternating-current generators built in this

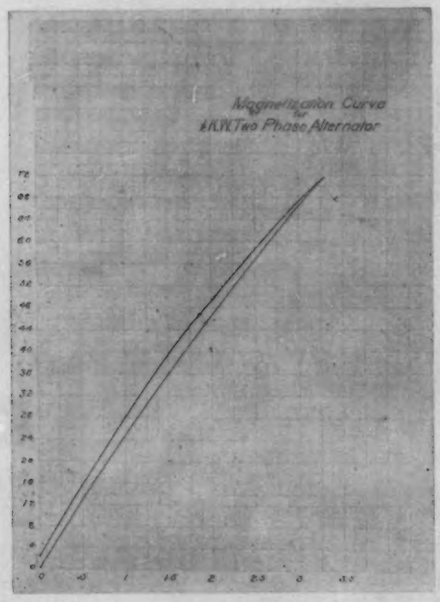

FIGURE 9.

country was very small. They were usually smooth-core machines, giving an approximately constant potential when separately excited from a direct-current constant-potential generator.

The Stanley alternating-current arc-generator, brought out by the Westinghouse Electric Company in 1889, was the most radical departure from this. In fact, it was a machine designed and constructed to give a constant current, up to a certain limit, no matter what the resistance of the external circuit might be; and the self-induction of the armature was made as large as was possible consistent with good efficiency and successful operation. The armature conductors were wound with a large number of turns in each coil, and placed upon large armature teeth. In fact, the construction of the armature core was almost identical

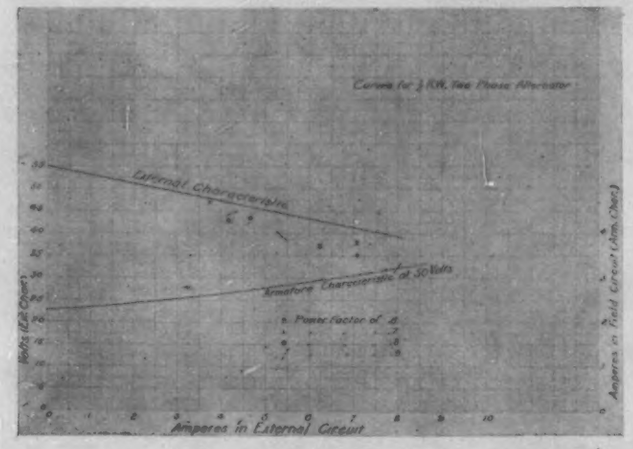
Curves for ½ K.W. Two Phase Alternator
External Characteristic
Armature Characteristic at 50 Volts
Power Factor of
Amperes in External Circuit

FIGURE 10.

with the machine upon which some of the experiments were made for the present paper.

The so-called distributed winding, or the winding which is adopted in a large number of machines made at the present time, where a comparatively small number of turns are placed in each slot, the slots being small and comparatively numerous to each pole piece, is a mean between the original smooth-core armatures

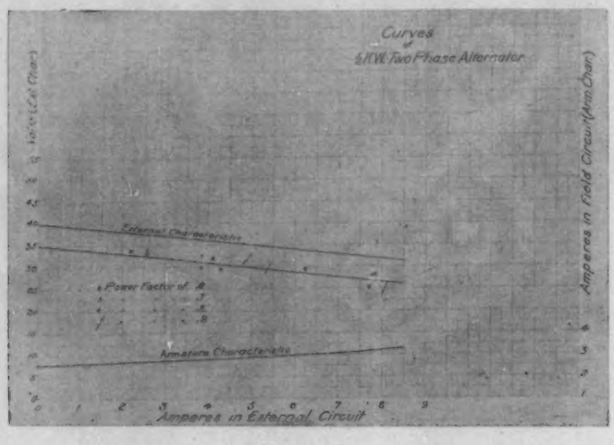

FIGURE 11.

and the alternating arc machine of Stanley. And hence, in taking up the experimental work, I have considered all three of these types. And perhaps it might be well to give a brief description of the machines, with some data regarding their constants.

The alternator having the smooth core is a small, one-half-kilowatt, two-phase, eight-pole machine, which was built in the Electrical Engineering Laboratory of the University. The winding consists of two

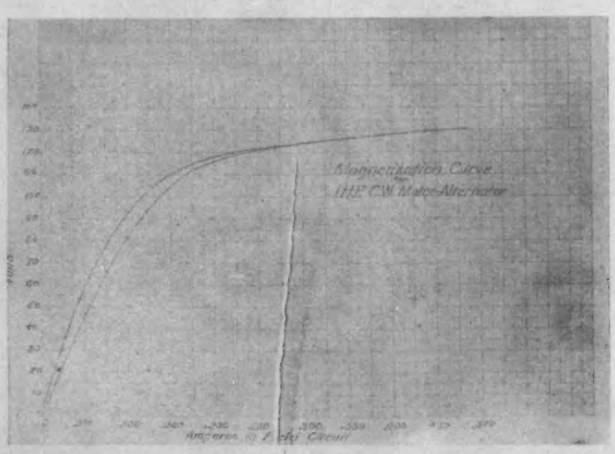

FIGURE 12.

layers and eight coils in each phase. The coils are the regular "pancake" coils, the winding of one phase being the lower layer next the smooth core, while the winding of the other phase consists of the second layer on the surface of the armature. During the experimental work the machine was run as a single-phase machine, the two windings being in series. The resistance of the armature was about 1.72 ohms; the voltage about 50; and the current output as high as nine

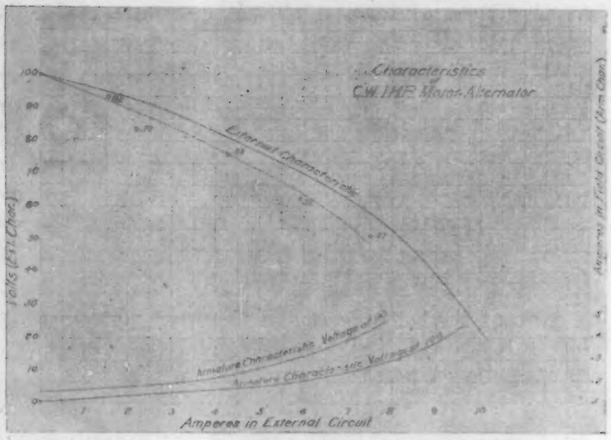

FIGURE 13.

amperes. This machine was separately excited from a 110-volt direct-current circuit. From its magnetization curve, it is evident that the air gap is rather large and that the iron is very lightly saturated. The self-induction of the armature was .0265 henrys. The curves show the regulation of the machine.

The second machine was a one-horsepower Crocker & Wheeler motor-dynamo, which was also equipped with a pulley so that it might be run and operated as a direct-current generator or as an alternating-current generator. During the experimental work, of course, it was operated as an alternating-current generator. It was run above speed considerably, because it was de-

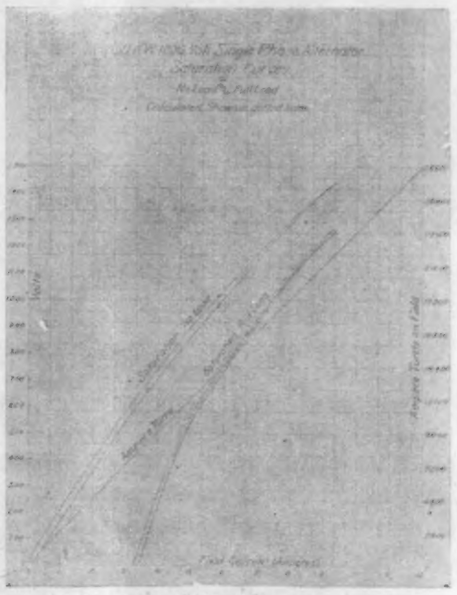

FIGURE 14

sirable to get the frequency as high as possible, this being a bi-polar machine. It was therefore run at two thousand revolutions a minute, giving about thirty-three cycles. The resistance of the armature was 2.1 ohms, and the self-induction .0323 henrys. The curves show the regulation of this machine.

The third machine experimented upon was a 30-kilowatt, 1,000-volt, single-phase alternator, of the toothed-armature type. The armature is wound with eight coils of No. 10 wire, 30 turns to the coil. The cross-section of the armature shows the arrangement of the winding.

In the armature, on diametrically opposite parts, is shown the series transformer, which is connected

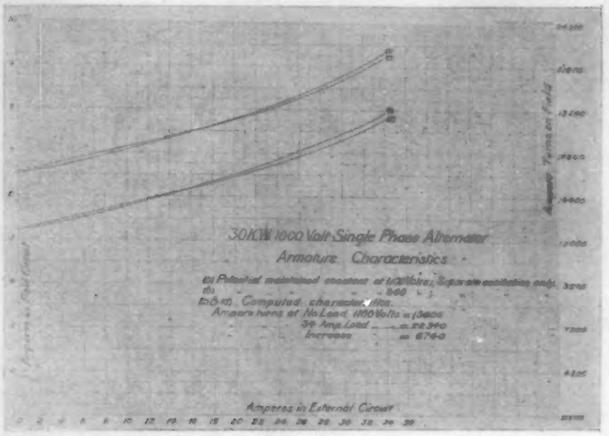

FIGURE 15.

through the rectifier for compounding the machine. The number of turns on the primary of these series transformers is five, and the number on the secondary is fifteen. The secondaries of these transformers are connected in series to the rectifier and at full load give about ten amperes. Inasmuch as the ratio of transformation is 1.3, the rectified current is one-third of the main current—the main current at full load being thirty amperes.

The eight poles of the machine are each wound with 300 turns for the separate excitation, or 2,400 turns total, and 175 turns for the compound or rectified excitation, or 1,400 turns total. The machine ordinarily runs at 2,000 revolutions a minute, which gives a frequency of about 133. The self-induction of the armature is, at full load, .02796 henrys, and the resistance .96 of an ohm. It should be noticed that the ratio of self-induction and resistance of this machine is much greater than the ratio of the self-induction and resistance of the smaller alternators.

In direct-current machinery the difference of poten-

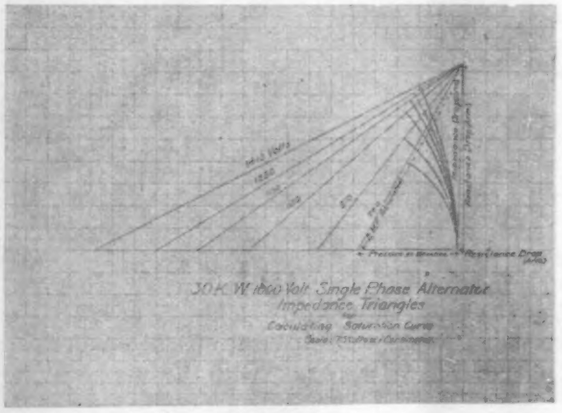

FIGURE 16.

tial at the brushes is equal to the electromotive force of the machine minus the drop in voltage due to the ohmic resistance of the armature. In alternating current machines, where the self-induction of the armature bears any considerable ratio to the resistance of the armature, the impedence drop is larger than the

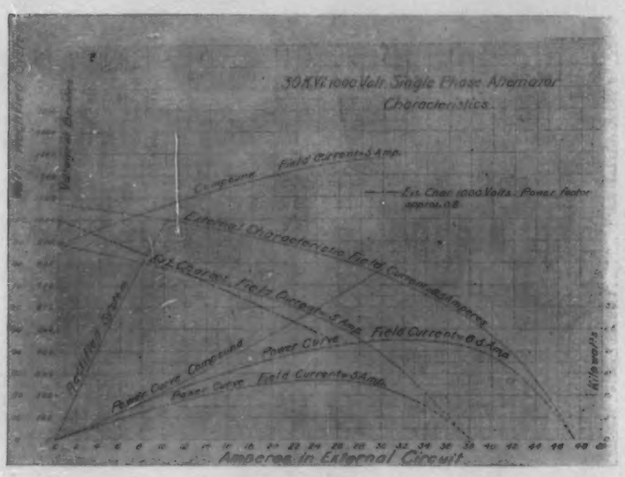

FIGURE 17.

ohmic drop. In order to determine the difference of potential at the brushes of an alternator, at any load, we cannot subtract the impedence drop through the armature from the whole electromotive force produced, because of a difference in phase. In other words, the difference of potential at the collecting rings, at any load, is not equal to the whole electromotive force generated minus the drop through the armature due to its resistance and self-induction. This must be clearly borne in mind in connection with the regulation of alternating-current machines, as regards the loss of pressure in the armature. The method of determining this

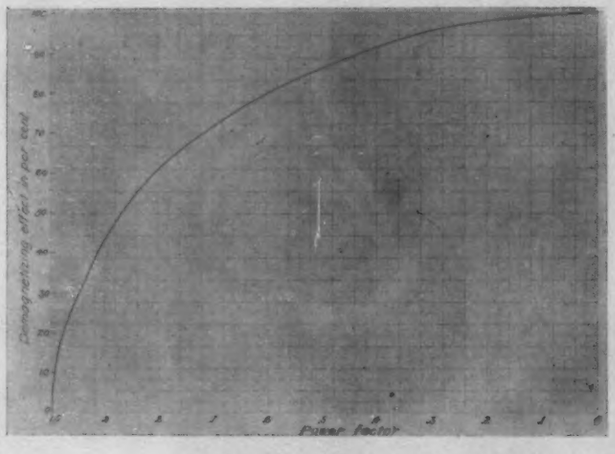

FIGURE 18.

drop through the armature and the difference of potential at the brushes, is clearly shown by the curves and the construction of the impedence triangles. The computed curves agree so closely with the observed curves that the results are quite satisfactory.

One point might be mentioned here which is apparent. If for any reason a smooth-core alternator is short-circuited, the almost inevitable result is the stripping of the conductors from the armature, due to the fact that the armature current increases far beyond its normal value.

If an alternator having separate excitation only is short-circuited, whose armature has a large self-induction, the current on short circuit is perhaps 200 per cent. of the full-load current, while the difference of potential at the brushes is practically nil. The power, therefore, is very small. Such generators, with only separate excitation, may therefore be short-circuited with no danger whatever.

The type of armature which is the mean between these two is perhaps most used at the present time, and may be said to have many advantages over either of the other forms.

The demagnetizing effect of the armature current in reducing the strength of field depends largely upon the

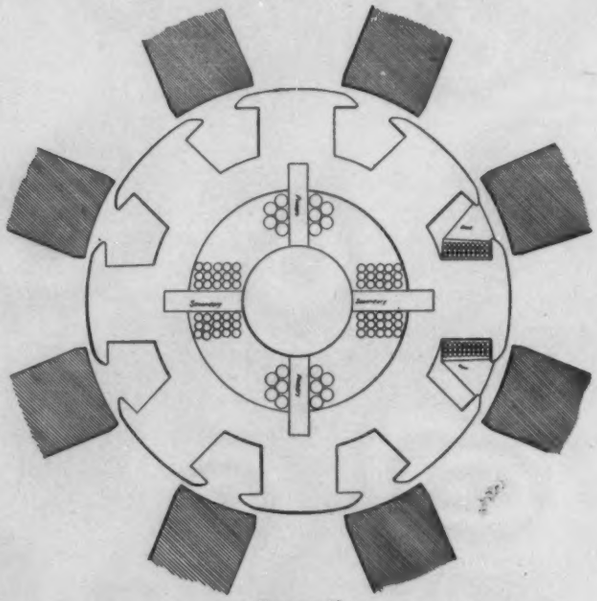

FIGURE 19.

power factor at which an alternating-current generator is operated. If the circuit is such that the capacity affected is large, producing an angle of advance between the current and the applied electromotive force, the tendency of the armature current is to add its effect to the field current in setting up magnetism through the armature and field cores and remainder of the magnetic circuit.

If the external circuit of the alternator has large self-induction, the current will lag behind the electromotive force, and the effect of the armature current will be to counteract the field current in setting up magnetization through the armature and field cores, etc. In mathematical language, this compounding effect of a leading current and demagnetizing of a lagging current is proportional to the sine of the phase angle. The cosine of the angle is always positive, no matter whether it is an angle of advance or an angle

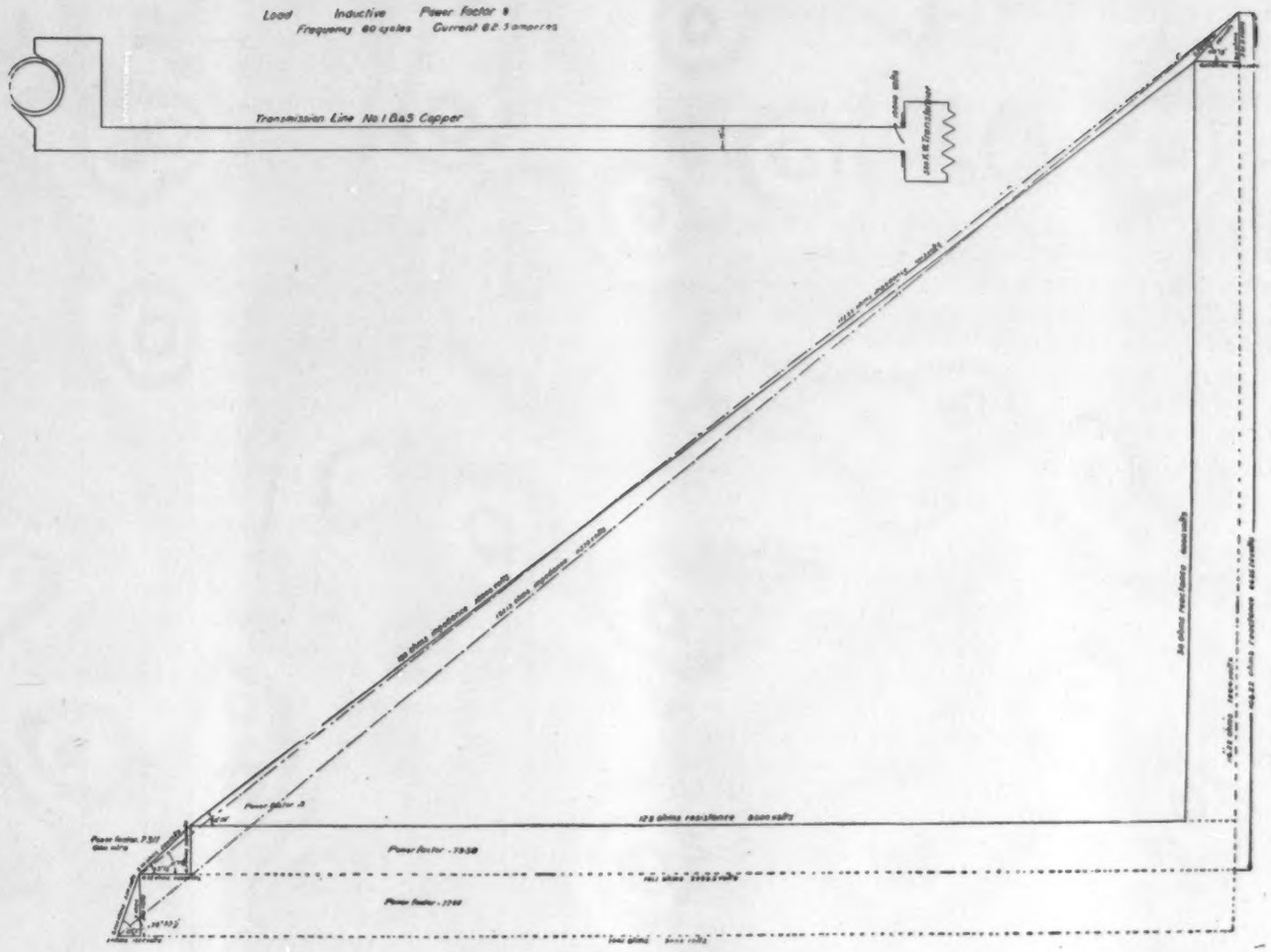

FIGURE 20.

of lag. Or, in other words, a leading current tends to over-magnetize the field, while a lagging current tends to demagnetize the field.

When an alternator with practically no self-induction in its armature is delivering current to a non-inductive circuit, the current is practically in phase with the electromotive force; the demagnetizing effect of the armature current of such a machine is practically zero, as may be shown by a simple illustration.

The demagnetizing effect of a lagging current is greater in an armature wound with a few coils, each of a large number of turns, than in an armature wound with a comparatively large number of coils of a few turns each. Consider an extreme case: Suppose that the current in an armature is lagging ninety degrees behind the generated electromotive force. The demagnetizing effect of the armature current is then at its maximum. If the armature is so wound that we have one coil for every pole piece, each armature coil containing a large number of turns, the current in this coil is a maximum when it is exactly opposite the pole piece—that is, when it is in position for maximum demagnetizing effect.

If this one coil, containing a large number of turns, is divided up into a number of coils of a few turns each, only a part of the original main coil is in position for maximum demagnetizing effect. This, therefore, is a distinct gain, as regards regulation, in favor of the distributed armature winding, or an armature winding of comparatively few turns in each coil and a large number of such coils or slots in the armature.

It should of course be noted that the form of the electromotive wave will also be affected by such a change in the armature winding. Indeed, in the machine experimented upon, the wave of the electromotive force is very peaked, or, as might be said, the third harmonic is very prominent.

In conclusion, it might be said that our modern dynamo, whether alternating or direct, and, if alternating, whether ploy phase or single phase, should possess five important features:

1. A high efficiency.
2. A low temperature increase when operating at full load.
3. Good commutation (reference only to direct current machines).
4. Good mechanical design and construction.
5. Good regulation.

These five features are interdependent, and each has greater or less importance. Upon the efficiency de-

pends the cost of power; and therefore the efficiency is of prime importance to the commercial success of any installation. Upon the rise in temperature depends the capacity, and in some cases the life, of the machine. In direct-current machines the commutation affects the regulation and capacity of the machine—indeed, in many cases, commutation affects the capacity of a direct current generator far more than the rise in temperature. Mechanical design and construction affects the reliability, the management, and, in a direct way, the operating engineer. The foregoing four features affect only the operating system or the operating company. Regulation, on the other hand, affects the customer, and is of more importance to him than any other matter except, perhaps, reliability of the electrical supply.

TABLE I.

Ten-mile, 10,000-volt (at receiving end), 500-kilowatt (at receiving end), single-phase transmission system; frequency, 60 cycles; line, a pair of No. 1 B. & S. copper conductors, 18 inches between centers.

	Load Non-Inductive Power Factor .99	Load Inductive Power Factor .8
Current in amperes	50.505	62.5
Power current	50.	50.
Reactive current	7.	37.5
Drop in the armature in volts	431.5	534.
Drop in the line in volts	905.	1120.
Watts lost in the armature	7652.	11719.
Watts lost in the line	33414.	51172.
Drop in line in volts in per cent	9.05	11.2
Watts lost in line in per cent	6.68	10.23
Total electromotive force of generator in volts	10985.	11570.
Voltage at collecting rings	10752.	11113.
Total apparent watts generated	554798.	723125.
Total real watts generated	541067.	562891.
Power factor of entire system, including armature	.9752	.7785
Power factor of load, including line, from collecting rings	.9821	.7936

TABLE II.

Power Factor in Per Cent. Cosine Angle of Lag.	Angle of Lag in Degrees.	Demagnetizing Effect in Per Cent. of Maximum Sine Angle of Lag.
100	0°	0.0
90	5° 45′	43.6
80	11° 33′	60.0
70	17° 27′	71.4
60	23° 35′	80.0
50	30°	86.6
40	36° 52′	91.7
30	44° 26′	95.4
20	53° 8′	98.0
10	64° 10′	99.5
0	90°	100.0

THE ROTATIVE DIRECTION OF POLYPHASE MOTORS.

Reversing the direction of rotation of induction motors is accomplished in general by interchanging two service leads. In particular, the two leads to be interchanged are as follows: Any two leads on a three-phase motor; the two leads of either phase of a four-wire, two-phase motor; and the two outside leads of a three-wire, two-phase motor. Synchronous motors will run in either direction as started.

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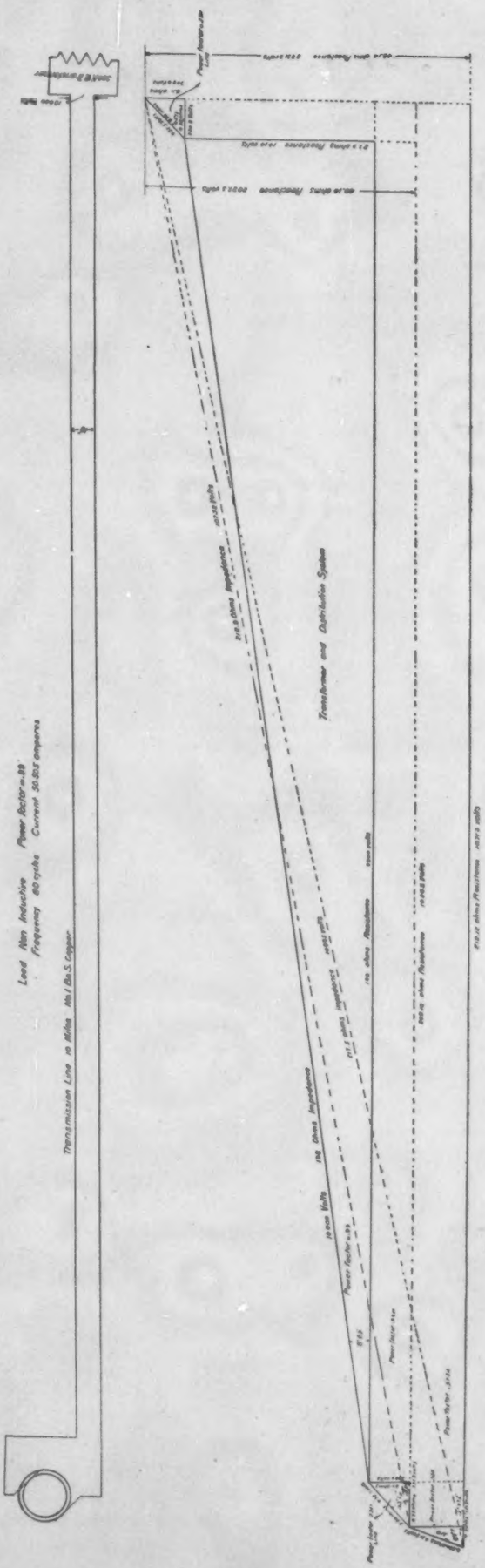


FIGURE 21.

Tests and Calculations for a Forty-Mile Aluminum Wire Transmission Line.*

BY F. A. C. PERRINE. D. SC.

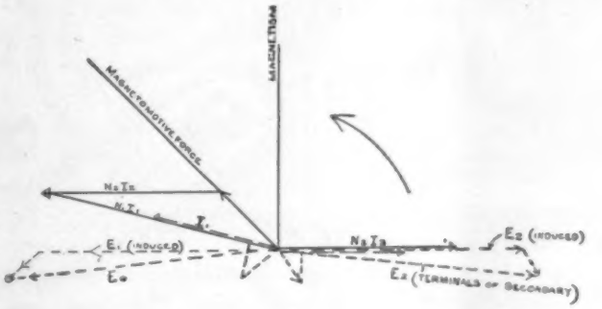
RUNNING from the Blue Lakes power house near the Big Bar bridge on the Mokelumne River to the Stockton sub-station is the line to which reference is made. It is that of the Standard Electric Company of California, and it is particularly pertinent to report on the tests of this line because there has been a great deal of talk about there having been a failure of the wire The line extends from the Blue Lakes plant on the Mokelumne River to the sub-station in Stockton, a distance given by the engineers as 43½ miles. The line was designed to deliver 1000 kilowatts at 8.8 per cent. C^2R loss, the line being two-phase, arranged at the corners of a rectangle—not a square; one side of the rectangle being 24 inches, the other side 41 inches, giving a distance between phases of 46 inches. This peculiar arrangement was adopted on account of the fact that the line was intended subsequently to be changed to a three-phase line, and to form with two additional wires, two three-phase lines on the one pole line; the wires being then set at the corner of a hexagon giving a distance of 41 inches between the wires of the same phase.

At present the two-phase line occupies four pins, and subsequently it is to occupy but three of the pins when the line is changed to three-phase. All of this was made necessary by the character of machinery, and also to overcome some of the difficulties which were anticipated in connection with the rapid building of the line, which rapid building was made necessary by the condition of the weather. The work began last November and no one had reason to suppose that the winter would be an open winter, which it proved to be.

The wire is 294 mils in diameter, or 86,433 circular mils in area, weighs 419.4 pounds per mile, and the ultimate tensile strength of each wire is 1539 pounds, or 22,700 pounds per square inch. The stress at one per cent. elongation is 800 pounds; conductivity by dimensions is 59.9 per cent. of Matthiessen's standard for soft copper. These quantities are obtained from the tests of a large number of samples. You will notice no elastic limit is given, but the stress is at one per cent. elongation. This is on account of the fact, that, in common with copper and metals of a similar character, aluminum has no well-defined elastic limit. As compared to a copper wire, this is the same as a No. 6 B. & S. in weight, a No. 5 in breaking stress, a No. 3 in resistance, and a No. 1 in capacity and inductivity. It is the same size as No. 1, and its resistance an equivalent to No. 3. But while it has only the weight of a No. 6, it has the breakage strength of a No. 5; so as regards the necessary strength in a span, the wire is equal to a copper wire of about 70,000 pounds tensile strength, or a steel wire of about 60,000 pounds tensile strength, steel, of course, being lighter than copper.

Taking up the question of resistance, which is exceedingly important as indicating whether this wire of low tensile strength, which was strung in warm weather and had been subjected to extremely cold weather, had stretched, we found that the resistance of the line was 92 ohms, which is the resistance for 42.8 miles. The engineers gave the length of the line as 43½ miles, so the resistance was about seven-tenths of a mile shorter than the measured distance. I am strongly inclined to think that this is on account of the fact that the engineers have chained the whole distance by individual pole distances, attempting to set all the poles 132 feet apart, and that when they came to a place where it was impossible for them to set them exactly 132 feet apart, they selected a favorable location at about at about 132 feet from the last pole; so, we have some few long spans and some few short spans. Finally obtaining the entire distance, they counted the poles, and, multiplying by 132, obtained a distance of 43½ miles. Whatever may have been the reason for the difference between these measurements, that difference in size and direction indicates very clearly that there was no permanent elongation of the wire during the cold weather.

The next test is one referring almost entirely to the insulators and the condition of the wire during bad weather. Fortunately there was some extremely bad weather during the time the tests were made on this line. The insulation of one wire against the ground was found to vary from 160,000 ohms on a rainy day to 44 megohms on a clear



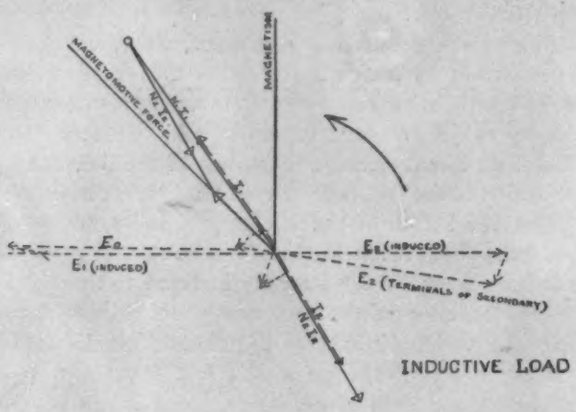
NON-INDUCTIVE LOAD

day. In fact, on one day during a shower the line would vary in a couple of hours all the way from five or six megohms down to a quarter megohm, but, under no conditions falling below 160,000 ohms.

As regards capacity, the wires one and two tested alone called for $3^{23}/_{100}$ microfarads as calculated, and the measure was $^{35}/_{100}$. As regards the self-induction: $^{164}/_{1000}$ by calculation and $^{17}/_{100}$ by measurement.

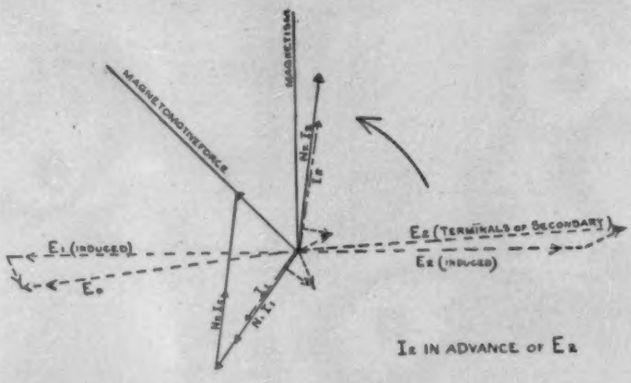
*A paper read before the Third Annual Convention of the Pacific Coast Electric Transmission Association, San Francisco, June 20-21, 1899.

There has been one point observed which has not anything to do with the line in a sense, but in another sense it has. And this was that the effect of the self-induction and capacity is to over-compound the step-up transformers. The step-up transformer ratio is 2300 to 25,000, and the step-down ratio 23,000 to 2200 with a possible variation of 200 volts in the regulator; but when current was put on the line without any load the voltage went entirely out



of the range of the regulator which seemed impossible with 25,000 volts initial. In fact, the voltage at the step-down station showed 27,200 on the line. There is a rise of potential at the end of the line due to the capacity; but it is only 200 volts, and a rise of over 2000 was observed which was entirely due to the transformers. A calculation from the constants of the transformers accounts for all but 200 volts of the rise, and an error in calculating the angle of lead in the transformer may easily account for this.

By calculation from the line constants it is seen that at no load on the step-down transformers the current leads the electromotive force by about 83 degrees. With 83 degrees lead the electromotive force at the secondaries of the step-up transformers ought to to be between 26,800



and 27,000 volts, and about 27,200 was observed. The explanation of the effect is quite simple, as may be seen by examination of the accompanying diagrams which present the three cases of non-inductive, inductive, and capacity loads with a constant primary terminal electromotive force. This effect is likely to appear in a very odd and more or less serious manner on long lines.

During these tests it was found that the capacity of the line varied materially with the state of the weather. The capacity between two wires would run all the way from three-tenths of a microfarad to .9 microfarad—three times its value—depending on whether it was raining or whether it had stopped raining, and so forth. If this occurs when the circuit is lightly loaded the current will swing clear around from lagging to leading and without a single change in the load, simply due to changes in the condition of the line, the electromotive force will go up and down. This is a condition to be provided for in our regulation, and calls for more regulation than has been commonly put in any of the sub-stations. The sub-station regulation is commonly figured out to be ample for the changes of load, but it follows that you must not only regulate for possible changes of load, but also for possible changes in the condition of the line which will throw the current from lagging to leading.

Gas

INDUSTRIAL GAS.—V.

BY FRANK H. BATES.

[THE HEMPLE APPARATUS—CONTINUED.]

THE explosion pipette consists of the thick-walled explosion-bulb *a*, Figure 15, and the level-bulb *b*, which are joined together by a wrapped piece of rubber tubing. At *c* two fine platinum wires are fused into the explosion pipette, the ends of the wires being about two millimeters (about $^1/_{16}$-inch) apart. At *d* is a glass stop-cock, and the pipette terminates in

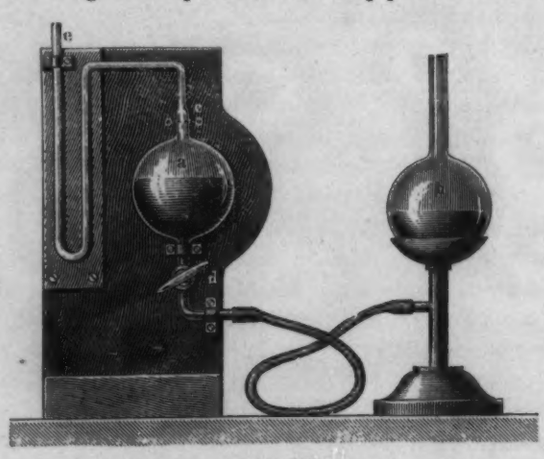


FIGURE 15.

the capillary *e*, whose end is closed by a short piece of rubber tubing and a pinch-cock. Mercury is used as the confining liquid, this tending toward greater accuracy, there being no absorption, with mercury, of the carbon dioxide formed by the combustion, as is the case when the explosion is made over water, as with the Elliott apparatus.

The hydrogen generator. When one is called upon to analyze gas mixtures which do not contain sufficient combustible ingredients to make them explosive when mixed with oxygen or air, combustibility may be produced by adding pure hydrogen. This may be prepared in the

special pipette, Figure 16. It is a compound absorption pipette which has two small bulbs in place of the first large bulb. Through the tube *g* a glass rod *h* is pushed up to the mouth of *e*. This rod is fastened tightly into *g* by means of a piece of rubber tube slipped over it, and it serves to hold pieces of chemically pure zinc in the bulb *e*.

To fill the pipette it is inverted, the glass rod is taken out, and the pieces of zinc are dropped into *e*. The pipette is then closed again, placed upright, and filled with diluted sulphuric acid (1:10) by means of a funnel with a very long tube attached to the capillary *i*. The hydrogen evolved during the filling frees the sulphuric acid from any absorbed air and at the same time fills the bulbs *b* and *c*. When 100 cubic centimeters of sulphuric acid have been brought into the pipette, some mercury is poured into *d*. The pipette is closed at *i* with a piece of rubber tubing and a pinch-cock. After a short time the hydrogen produced will drive back the acid so that the evolution ceases; the mercury prevents the entrance of air into the apparatus, and pure hydrogen is always ready. It is advisable to force a little water into the capillary tube *i* to prevent the entrance of air at this point. A few pieces of platinum foil may be put in with the zinc to increase the evolution of hydrogen.

Explosion pipette with electrodes for the decomposition of water. A form of explosion pipette within which hydrogen and oxygen are set free by the electrical decomposition of the water contained, is shown by Figure 17. This is applicable to analyses in which the error due to the explosion being made over water will not be of consequence. Two platinum electrodes are placed in the body of the pipette, and some little distance below the line of the surface of the water when the gas is contained. These are connected by wires to a battery. Having the gas within the pipette, the battery connection is made, causing a current to pass between the electrodes through the water, separating the latter into its elementary constituents, hydrogen and oxygen. A little practice will serve to guide one as to the amount of gas required. After disconnecting the battery, connection is made with the sparking wires and induction coil, causing a spark to pass through the gas mixture and thereby igniting the gases hydrogen and oxygen resulting from the decomposition of the water. The generations of heat and pressure in connection therewith is sufficient to ignite the gas itself, which explodes, giving a sharp tick. No account need be taken of the amount of hydrogen and oxygen formed by the decomposition of the water, since on burning they return to the former state in the same proportion.

FIGURE 17.

The combustion of the methane and hydrogen in a gas mixture may be effected without explosion, by bringing

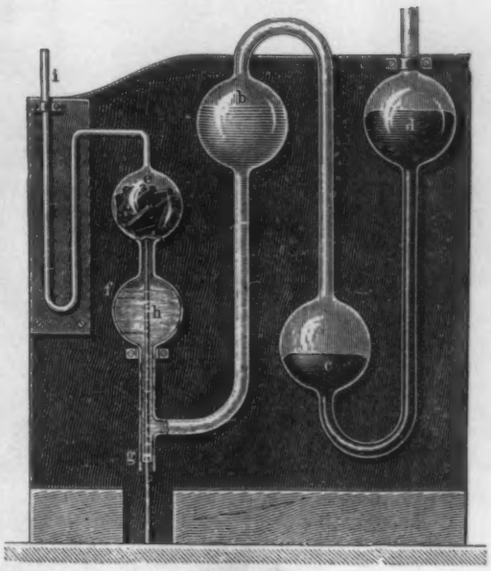


FIGURE 16.

the mixture in contact with a wire heated to redness in a pipette similar to that used for solid; see Figure 18. As this method offers no advantage and requires more time for operation than the explosion pipette, a detailed description will be omitted.

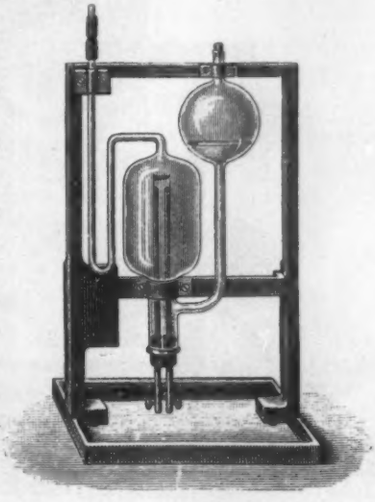


FIGURE 18.

Operation of the Hemple Apparatus. In analyzing a mixture of gases with this apparatus the gas is successively passed through the several pipettes, simple and compound, containing the reagents, after which a portion of the gas residue (portion remaining after the absorptions are complete) may be passed into the explosion pipette and burned with oxygen to determine the hydrogen, methane, and nitrogen; or, for the latter operation may be substituted fractional combustion, in which case the hydrogen is first and separately removed by palladium, after which the methane is ascertained by use of the explosion pipette.

Manipulation of the absorption pipette. The measuring burette *b*, Figure 19, must first be filled with water previously saturated with the gas under examination.

The contents of the simple pipettes must also be saturated with the gases but slightly soluble in them. The contents of the compound pipettes remain saturated for an indefinite time owing to the enclosure of a volume of gas between two bodies of liquid.

Draw into the measuring burette *b* 100 cubic centi-

meters of the gas to be analyzed, method for doing which has already been described.

Note that the reagents of each pipette are brought to a position close to the upper end of the white background, generally found attached to the frame of the pipette and in the rear of the capillary tube. It would be advisable to make a mark here (see E, Figure 19), that it may serve as a guide.

Connect the measuring burette *b* containing the 100 cubic centimeters of the gas sample, to the first pipette by

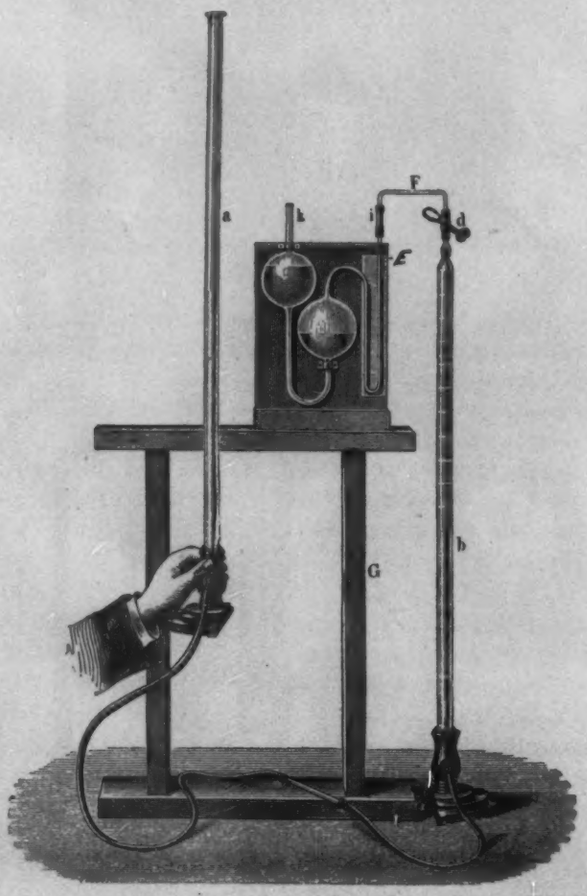


FIGURE 19.

means of the capillary tube F and rubber tubes *d* and *i*. In making up the connections with the capillary tube F, observe all the precautions heretofore cited, seeing that no air is permitted to remain between the pinch-cocks at *d* and *i*. It is advisable to use a pinch-cock at *i* as well as at *d*. To prevent the enclosing of air, fill the rubber tube *d* above the pinch-cock with water by means of a small dropping pipette; then insert the bent capillary which becomes filled with the water displaced. By now compressing that portion of the rubber tube *i* which is above the pinch-cock, and at the same time introducing the free end of the capillary, the connection may be made without enclosing air. If, however, by some slip, there should remain any air bubbles, they will appear at the beginning as the transfer of the gas is made. In event of their not exceeding a total length of, say, 10 millimeters (⅜-inch), in the upright capillary tube of the pipette, they may be disregarded, since that would be indicative of but 0.03 of a cubic centimeter or of an error of $^{3}/_{100}$ of one per cent.

With the reagent in pipette at the mark E, open the pinch-cocks at *d* and *i*, having previously raised the level-tube *a*. Force the gas into the pipette, allowing a little water to pass over into the pipette also, to make certain that the entire gas volume is transferred. Close the pinch-cocks at *i* and *d* and disconnect the measuring burette without removing the capillary F from the rubber tube connections above the pinch-cock at *i*. This leaves the pipette, containing the gas, free to agitate, rendering the absorption more rapid.

After allowing sufficient time to elapse to complete the absorption of this constituent of the gas mixture, the pipette is reconnected to the measuring burette, observing the same precautions as regards the enclosing of air, and the gas transferred by lowering the level-tube.

Bring the reagent to a position in the upright capillary corresponding to the mark E, when close pinch-cocks at *i* and *d*. Measure the volume of the gas in the measuring burette under atmospheric pressure by taking the reading with the level of the liquid in both level-tube and measuring burette at the same height.

Subtract this reading from the last, and in this case (the first absorption) the reading is 100 cubic centimeters, (the amount of the gas mixture taken for a sample) and the result will be the cubic centimeters of absorption or the percentage of the constituent absorbed. The percentage in each case will be slightly in excess of the true absorption, due to the gas remaining within the capillary F, but this is hardly to be considered of consequence, although allowance may be made by measuring the capacity of the bent capillary.

The manipulation of the compound pipettes is exactly similar, and of the pipettes for solids, the only difference lies in the case of the latter, in which the gas is exposed to the action of the solid reagent and requires no agitation as is best done to quicken the operation with a liquid reagent. By means of the Hemple pipettes, all waste is avoided, the reagents being used over and over again until exhausted.

After using, the pipettes are closed at the capillary end by the insertion of a short piece of glass rod in the rubber tube connection *i*, releasing the pinch-cock to prevent the rubber becoming set, and by closing the end of the glass tube *k* with a small cork.

It is advisable to keep an accurate account of the absorptions in cubic centimeters on the back of each pipette, so that, knowing their absorbing capacity, their full strength may be realized.

By not allowing any of the reagent to run over into the measuring burette, it will always remain clean; but should this occur, its simple construction permits of its being rinsed without trouble.

An analysis of coal gas will serve to illustrate the use of the various pipettes:

The measuring burette filled with water saturated with the gas under examination. 100 cubic centimeters of gas,

measured under atmospheric pressure, admitted to the measuring burette.

The gas transferred from the measuring burette to the first pipette, a simple pipette containing potassium hydroxide. After thoroughly agitating the gas with the reagent, it was drawn back into the burette. After a lapse of three minutes to allow the burette walls to drain, the volume was measured and found to be 99.6 cubic centimeters. This, subtracted from 100 cubic centimeters, gave the percentage of carbon dioxide:

$100 - 99.6 = 0.4$, or $CO_2 = {}^1/_{10}$ of 1 per cent.

Gas was passed into the second pipette, a special pipette containing bromine. After agitating, the gas was returned to the measuring burette, and then, previous to measuring, passed into the first or potassium hydroxide pipette, to remove the bromine vapors. Returned to measuring burette, and after a lapse of three minutes gas volume measured and found to be 95.3 cubic centimeters. This, subtracted from the last reading, 99.6, gave the percentage of fixed illuminants or heavy hydrocarbons:

$99.6 - 95.3 = 4.3$, or $C_2H_4 = 4.3$ per cent.

Instead of employing bromine, fuming sulphuric acid might have been used for the absorption of the heavy hydrocarbons.

The gas was passed into the third pipette, a compound pipette containing potassium pyrogallate. After agitating, the gas was returned to the measuring burette, and after a lapse of three minutes, gas volume measured and found to be 94.8 cubic centimeters. This, subtracted from the last reading, 95.3 cubic centimeters, gave the percentage of oxygen:

$95.3 - 94.8 = 0.5$, or $O = {}^1/_2$ of 1 per cent.

Instead of employing potassium pyrogallate, phosphorus might have been used for the absorption of oxygen.

The gas was passed into the fourth pipette, a compound pipette containing ammoniacal cuprous chloride. After thoroughly agitating, and allowing to remain in contact with the reagent some three minutes, the gas was returned to the measuring burette, and after a lapse of three minutes gas volume measured, and found to 87.1 cubic centimeters. This, subtracted from the last reading, 94.8 cubic centimeters, gave the percentage of carbon monoxide:

$94.8 - 87.1 = 7.7$, or $CO = 7.7$ per cent.

Instead of employing ammoniacal cuprous chloride, cuprous chloride might have been used for the absorption of carbon monoxide, the former being required only when palladium is used for the absorption of hydrogen.

The 87.1 cubic centimeters of gas now remaining, termed the gas residue, transferred to the ammoniacal cuprous chloride pipette, which served simply as a holder. The measuring burette thoroughly rinsed out with hydrochloric acid and water and refilled with water saturated with air.

A little of the gas residue (from 12 to 20 cubic centimeters) was drawn into the measuring burette, and after a lapse of three minutes gas volume measured, and found to be 14.5 cubic centimeters. This was transferred to the explosion pipette, after having added some 15 cubic centimeters of air, and oxygen sufficient to bring the total volume up to 100 cubic centimeters. In making the transfer from the measuring burette, care was taken to have a little water pass over, and the rubber connecting piece was closed by a strong pinch-cock so as to confine the water within the pipette capillary. A piece of glass rod was also slipped into the open end of the rubber tube above the pinch-cock on the measuring burette being disconnected. The pipette was then thoroughly agitated to mix the gas, oxygen and air, the glass stop-cock closed, and by connecting to the induction coil and battery a spark was passed causing the mixture to explode. The glass stop-cock at once opened, and the gas transferred to the measuring burette, where, after a lapse of three minutes, gas volume was measured and found to be 76.05 cubic centimeters. This, subtracted from the total amount before the explosion, 100 cubic centimeters, the contraction:

$100 - 76.05 = 23.95$ cubic centimeters contraction.

The gas was now transferred to the first pipette, containing potassium hydroxide, and, after agitation, returned to the measuring burette, where, after a lapse of three minutes, the gas volume was measured and found to be 70.15 cubic centimeters. This, subtracted from the former reading, 76.05 cubic centimeters, gave the carbon dioxide formed, which is equal to the methane:

$76.05 - 70.15 = 5.90$ cubic centimeters = methane.

The gas was now transferred to the potassium pyrogallate pipette, to make certain there had been oxygen in excess,* and, after agitation, returned to the measuring burette. After a lapse of three minutes, the gas volume was measured and indicated an absorption of oxygen.

(Continuation in next number.)

Personal

J. N. THOMAS, late of the Johnstown Steel Rail Company, and more recently of a well known electrical engineering office of New York City, is visiting relatives in Santa Rosa and will locate in California, if possible.

CHAS. E. SEDGWICK has resigned the assistant managership of the power and mining department of the San Francisco office of the General Electric Company, and has accepted the position of general manager of the Hilo Electric Light Company, Hilo, H. I.

E. M. FRAZER, inventor of the Frazer electric elevator, the patent rights for which have been sold to the Otis Elevator Company, has gone to Chicago, having accepted the position of electrical superintendent for the Otis company in building Frazer elevators.

NORMAN ROWE, late of the engineering staff of the Westinghouse Electric and Manufacturing Company, Pittsburg, has been appointed electrical engineer of the San Francisco office of the Westinghouse company, taking the place of R. S. Masson who resigned some weeks since to accept the position of superintendent of the Independent Electric Light and Power Company, San Francisco, as previously announced.

The *American Electrician* in making an abstract of the description of Kootenay-Rossland transmission appearing in this publication, concludes by saying: "These facts are taken from an illustrated description of the system published with the usual clearness and thoroughness of illustration characteristic of *The Journal of Electricity*.

*This is a needless precaution in our case since oxygen was added in excess.

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EDITORIAL.

THE ELECTRIC TRANSMISSION CONVENTION.

Prominent among the many profitable results of the recent convention of the Pacific Coast Electric Transmission Association, were the ideas brought about by the reading of papers upon the lines of rates for service and electric power in pumping, as well as those which followed Dr. Perrine's inquiry for expressions of opinion from practical men in regard to the insulation of pins, cross-arms and poles on high-tension lines. Equally instructive and interesting were the theoretical papers read on the calculation of transmission lines and on the regulation of alternating-current generators. In this issue appears the last of the papers read before the convention, while the final installment of their discussions will appear in the next number.

Without doubt the most valuable paper brought before the Association, and which, at the same time, is most pertinent to the majority of transmission managers who are looking towards pumping for irrigation purposes as a means of evening the load factor, was that by Mr. Lewis A. Hicks, C. E., on electrically-driven centrifugal pumps. Anyone who enters into this subject with the thoroughness with which Mr. Hicks has, is surprised at the paucity of information existing upon the subject, and his surprise grows to astonishment when he realizes that the views held on centrifugal pumping even five years ago are now of but historic interest. Indeed the last stepping stone in the literature on centrifugal pumping prior to that of Mr. Hicks' paper just referred to, was the essay by John Richards, M. E., published in 1894; and here the thought impresses one that the so-called "infancy" of electricity is prime manhood in comparison with the narrow advances that kindred sciences, though far older, have made during its comparatively limited existence. The fact is, that were problems concerning the design and operation of water wheels and centrifugal pumps, for instance, as carefully worked out as have been the designs of electrical machinery, the operation of water power and pumping plants would be simplified beyond measure. To illustrate: Is there a water wheel governor that gives regulation within that of a well-designed station transformer? Is there a water wheel in service that can approach a working efficiency within fifteen or twenty per cent. of that of an electric generator, or is there a centrifugal pump the efficiency of which can approach that of an electric motor by from thirty to forty per cent.?

It is probable that long before the United States Government or the state of California, or both, has gone through the tedious routine preparatory to the building of impounding reservoirs as prayed for by the mining, agricultural and transmission interests of the State, that the question of load factor in the majority of transmission plants will have been brought up to a high percentage in the majority of installations through the use of electric pumping service. Loads of this character are extremely flexible and any effort towards analyzing the losses in methods now in vogue, with a view to increasing efficiencies, is a stride towards the development of a line of business destined to be a safeguard in the economical administration of transmission plants. Mr. Hicks' paper is, therefore, much more than a technical discussion of the performances of centrifugal pumps; it is an exponent of the improvements that can be made in, and the profitable business that can be derived from, the operation of electrically-driven centrifugal pumps for irrigation and other purposes.

While the operation of these applications of pumping have heretofore been mainly confined to transmissions in the San Joaquin Valley, it is probable that the coming spring will witness the exertion of almost herculean efforts to unwater the Comstock mines by the application of electric power. This will mean the lifting of from seven to ten millions of gallons of water daily against heads varying from a few hundred to much more than a thousand feet under conditions of extreme dampness, high temperature, and, in some cases, narrow confinement. Here again may be repeated what has almost just been stated: the most serious problems to be encountered in the Comstock mines will be of mechanical and hydraulic rather than of electrical natures, for there is no question but that electricity will do its allotted work reliably and efficiently. The best form of pumps to be used, however, is not so easily determined as is the type of electric motor suitable for the service in direct connection for sinking purposes; and it now looks as though the next year or so would bring about new forms of sinking pumps, of compound centrifugal forms, or of adaptations of the Quimby principle in order that increased efficiency and simplicity may be attained through direct connection to the motive power. It is not to be questioned that the pursuit of investigations along these lines is of inestimable value to transmission interests.

While the subject of insulating pins and cross-arms on high-tension lines was under consideration, Mr. R. M.

Jones startled the convention by expressing the opinion to the effect that the use of potentials in excess of 50,000 volts for long transmissions would necessitate the placing of each transmission line, or rather wire upon a separate pole line before any assurance of reasonable immunity from insulation break-downs could be had. Though this suggestion seems a radical departure from existing practices, it is by no means without precedent in the annals of other branches of electrical industry; witness, for instance, the mighty protest that went up from tens of thousands of electrical concerns from the Atlantic to the Pacific at some of the revolutionizing requirements of the boards of fire underwriters. The utter annihilation of the incandescent electric lighting business was prophesied because of the then believed-to-be prohibitive cost of wiring thus entailed, but time has proven that the exactions were those of wisdom and prudence. So, too, may the hundred-mile-or-more transmission find commercial feasibility through the use of extremely high potentials carried on single-wire pole lines erected in accordance with Mr. Jones' suggestion. The dismal failure of the 40,000-volt line in Utah came like a shock because of the previously glowing accounts of it which had been received; but now that the truth is prevailing, it seems patent more than ever that the use of such a potential in a mountainous country is impossible with the ordinary form of construction installed. It will be said that the construction of the line referred to was by no means an ordinary one; that it was far below the ordinary, and that it was most wretched. Even so, and considering also the fact that the neutral of the line was grounded, the fact of the repeated burning-out of cross-arms and poles indicates the necessity for some radical change in the form of construction if such voltages are to be used.

As the lengths of transmission and the potentials of line currents go onward and upward, the questions of line insulation grow of ever increasing importance. The business public will not accept financial risks under any condition other than that where every assurance has been made doubly sure, else why should the relations between the mortgagor and the mortgagee, for instance, be so clearly defined in business ethics? On the same reasoning, it does not appear to be wise for the transmission engineer to entrust the insulation of his line, which is a vital question from every standpoint, to the insulator alone, when the insulation of the insulator may be strongly reinforced by insulating the pin and cross-arm to the highest possible degree. Granted that the insulator is reliable, it can then only be said that if the engineer has further increased its reliability by insulating pins and cross-arms, he has done no more than that which commercial prudence dictates in the demand that every assurance shall be doubly sure.

The title of Mr. Martin's paper—"Electric Lighting versus Gas"—suggested a revival of the old feud between the two modes of illumination that are foremost in public favor, but it is positively refreshing to note the spirit of fairness that pervades it. It is not necessary to refer to the discussion, however, to know that his enlightened ideas on the subject are not entirely those of the electrical community, and it is a source of regret to realize that—to borrow from the paper—"blind prejudice" is far from being unknown to the minds of many managers of both gas and electric plants. These columns have repeatedly emphasized the conviction—and they do so again at the risk of redundancy—that the antagonism between gas and electricity as a means for serving the public with light and power, is altogether unnatural, unwarranted, and unprofitable, and an awakening to this belief by both interests would probably be more beneficial to their earning capacities as would the elimination of their bonded indebtedness. The enormous commercial interests involved in the conversion, transmission and distribution of energy, whether for purposes of light, heat or power, or whether by water or steam power, gas, compressed air or electricity, are all most intimately related, and have common cause to which unprejudiced and unswerving devotion will advance to an indefinite degree for the general good.

The old question of meter rates, and its long line of attendant *et ceteras*, was revived by the reading of Mr. Martin's paper, but interest therein would probably not have advanced beyond the commonplace had not Mr. Hutton opened an original line of reasoning by suggesting a practical means for the determination of equitable rates. Mr. Hutton's paper is pregnant with matured conclusions upon a subject of vital interest to every plant of whatever nature that has to do with obstinate load factors, and as such it can hardly fail to become recognized as among the classics of central station literature.

If copper producers and wire merchants had taken second thought and had realized that the day has at last arrived when it is no longer necessary to use copper for electric transmission lines, it is possible that the price of copper would not be quite so high as it is at present. It was singularly opportune for manufacturers of aluminum that the price of copper went skyward just as they had perfected processes for the production of pure aluminum in unlimited quantities. The result has been that the inflation in the price of copper has done infinitely more toward the introduction and use of aluminum in line work than it would have been possible to have accomplished in a decade of education through the pursuit of the ordinary means of hum-drum talk by well-drilled selling agents. Dr. Perrine's paper afforded the means for focussing the attention of the Transmission Association upon the use of aluminum for transmission purposes. Much valuable information concerning the use of that metal for electrical conductors was given by Mr. Lee, and Prof. Cory added an outline of tests which have been under way at the mechanical laboratory of the University of California—all distinctly favorable to aluminum. Thus, one by one, are being swept away the phantom arraignments alleging the unfitness of aluminum for electrical purposes. Transmission interests have cause for jubilation that they are now disenthralled from complete bondage to the copper

kings, for which thanks should be given largely to the cupidity of the copper kings themselves.

The very practical and concise paper by Mr. Van Norden brought out two interesting themes for discussion. First, electromotive forces as high as 16,000 volts are far more tractable than was formerly supposed; witness their confinement by telegraph insulators and paraffined pins through winds and rains as Mr. Van Norden relates. This, however, is according to the experience of the Pomona plant (though there the potential is but 10,000) where for two or three years no effort has been made to replace broken or shot-off insulators unless the insulator is entirely demolished and the line drops to the cross-arm. The result is that a motley assortment of apparently wrecked glass insulators are still in service, but their utility nevertheless seems to be evidenced by the fact that they still prevent the occurrence of appreciable leakage. For this, however, thanks be given to the climate of southern California alone. It is not contended for a moment that carelessness in replacing broken insulators, or in using telegraph insulators even temporarily, is to be condoned at any ordinary time. Meschech, Shadrach and Abednego are also reputed to have walked through a fiery furnace without singeing a hair, but an attempt to do such a thing to day would be considered an evidence of idiocy by even the blindest fanatic. It is not supposable that transmission engineers are going to tolerate the continuance of broken insulators in service or consent to the reduction of the size of glass insulators, even though the Pomona line runs on petticoatless glass stumps, and even though the Central California line found that telegraph insulators proved serviceable during a famine in standard types of high-tension insulators.

Secondly, Mr. Van Norden has found from experience that the synchronizing of generators in widely separated stations is easily accomplished; in fact, to quote his paper: "The distance seems to have a cushioning effect and it is not by any means so necessary to have the generators so near in synchronism when thrown together as when side by side." Mr. Jones' remarks gave this opinion a strong endorsement in citing the experience of the Big Cottonwood and Pioneer stations in Utah, which are synchronized with perfect ease though some fifty miles apart. When to this is added the remarkable combinations of steam, water power, street railway, Edison three-wire, single-phase alternating, and multiphase transmission plants in daily operation in southern California, part of which were described in detail in the San Gabriel edition of the JOURNAL, it will be seen that the synchronizing of practically any portion or portions of modern electrical machinery is no longer a subject to cause the slightest hesitancy in the plans of electrical engineers.

Prof. Cory's paper on the regulation of alternating-current generators is given as the leading article in this issue, and its perusal will show that its writer has made a very clear and comprehensive exposition of the principles which underlie that which is ordinarily considered to be a complex subject. Space forbids a detailed consideration of the questions involved under this heading, albeit they are of the utmost importance in electrical transmission work, and it is a misfortune that the literature available upon the subject is so almost incomprehensible to the ordinary reader. Prof. Cory's paper is, however, exactly in the right direction, and it is fitting to express the hope that the initiative he has so ably taken may soon be followed by other productions which will clear the minds of the electrical masses of much of the doubt now existing concerning the inherent regulating qualities of, for instance, revolving armature, revolving field, and inductor types of generators under the trying conditions imposed in long transmissions for heavily-fluctuating power service. Upon this point hinges the perhaps bitterest contentions among advocates of the different types of polyphase generators, and the sooner the atmosphere is cleared the better for all.

As to the Association itself, too much stress cannot be laid upon the words of the new president, Pce. A Poniatowski, in closing the session, for they bespeak a thorough cognizance of its aims and needs. While the Association is flourishing, it must be confessed that there is some dissatisfaction with the rule that has been in vogue of having only annual meetings. President Poniatowski leads those who are distinctly opposed to the idea that all there is of mutual interests to be said concerning transmission matters can be said at a meeting to be held once a year. Indeed, there is no other field wherein the necessity for frequent intercourse between members is more necessary than in that of the electrical transmission of power. Other lines of industry are older and their methods have settled down to well-defined practices, and while the latter is true to a great extent in electrical transmission work, there yet remains an abundance of material to be threshed out in the light of the experiences of different installations under widely different skies. As yet no definite plan has been formulated for more frequent meetings, but it is probable that the holding of quarterly meetings will be determined upon, the first of which may occur in October. As suggested in the President's remarks, the papers to be presented at meetings hereafter will be printed at least a fortnight beforehand and submitted to members that they may be prepared to discuss the subject matter intelligently, after having had the opportunity to digest the papers under discussion.

The Transmission Association is thriving as no other organization of the kind on the Pacific Coast has done; it is working in virgin soil under especially favorable conditions, and the wealth of experience of its members constitutes information that is sought for by electrical engineers the world over. Nature has so endowed its surroundings that the Association has a mission to perform for electrical engineering, and that it will do it well is not to be doubted.

Live Steam and the *Engineers' Magazine* have consolidated and now appear as *Steam Engineering*—a very worthy publication.

The Third Annual Transmission Convention.

Official Report of the Discussions which Followed the Reading of the Papers at the Association Meeting Held in San Francisco, June 20-21, 1899.

PRESIDENT W. Frank Pierce called the Third Annual Convention of the Pacific Coast Electric Transmission Association together at the Cliff House, San Francisco, on the morning of June 20th last, as previously announced in these columns, and, after a few graceful remarks pertinently referring to the prosperous condition of the Association, and the powerful influences for good which it is exerting, immediately proceeded to the transaction of the business at hand, the first of which was the delivery of a paper by F. A. C. Perrine, D. Sc., on "Tests and Calculations for a Forty-Mile Aluminum Wire Transmission Line." This paper is reproduced on page 41 of this issue.

PROF. CORY: Mr. President, I would like to ask one question of Prof. Perrine. By what formula did you compute the capacity of your line?

PROF. PERRINE: I computed it in two ways: by the simple formula, and then I worked it out in the most complicated Heaviside method, and I did not find the complicated method gave any better results than the simple one. I came to the conclusion that the ordinary equation for the capacity of two parallel conductors in air, gave results within the limit of the errors of the instruments, and I do not see any use going into it further.

PROF. CORY: These computed results then which you give were obtained by the use of this formula

$$C = \frac{1.11 \times 10^{-6}\ k\ l}{4 \log_e \frac{d}{r}}$$

Where k is specific inductive capacity (for air, unity).
l is length of conductor in centimeters.
d is the distance between conductors in centimeters.
r is the radius of conductor in centimeters.
C is the capacity in microfarads.

THE CHAIRMAN: Gentlemen, have you anything further to submit on this subject which we have had before us for discussion?

MR. GILBERT: I would suggest we might hear something in the abstract upon aluminum. We have representatives of the aluminum company here, and they might be able to offer something.

THE CHAIRMAN: Mr. Lee, will you give us some information on the subject?

MR. LEE: In the abstract there is very little to be said, and I think most of the points which have been brought out, by Dr. Perrine in particular, were a good deal more interesting than those in the abstract would be. One of the most striking stories that have been circulated is one that was published in the San Francisco papers some months ago, and at the time I was not very certain about it; I thought it might possibly be true, and I therefore did not say anything until I could ascertain what the experience really had been. It seemed that somebody from the Arizona copper district came up here—incidentally he was very much interested in copper—and he made the broad statement to some reporters on the newspapers that aluminum was a failure. He made a very flat statement, and he based it, he said, not on any theoretical conditions, but on an absolute experience of the Pennsylvania Railroad that the life of aluminum wire was six months or thereabouts; of course, under certain favorable conditions it might last seven, but at that time that was about the limit of its life. Exactly what happened to it he did not state, but I presume it was that the wires disintegrated. The case he took in point was that of the Pennsylvania Railroad. I communicated with our factory as to whether it had been a success; they replied that the superintendent of telegraph had ordered a good deal more aluminum and that they were getting it out as fast as they could.

Prof. Perrine states that the comparative conductivity is sixty per cent., and in practice we use sixty per cent. greater cross-section. From the tables that are given of copper we find by reference to the cross-sections, that by using wire two sizes larger we get practically the same conditions as regards conductivity; sometimes a little in excess and sometimes a little less. We have adopted this rule for convenience and so as to conform to the Standard wire gage. Nearly all the tables in existence are those of B. & S. copper wire, giving the data on copper wire, and to avail ourselves of those tables we have laid down that rule. As regards the question of weight we find that it is practically 48 per cent. of that of copper of equal conductivity. That is to say, if you had a certain span of wire, copper, of given conductivity, and weighing 100 pounds to the span, a span of aluminum of equal conductivity and length would weigh 48 pounds.

Aluminum, of course, is rather susceptible to alkalies, but is not affected to any great extent by acids; and the Sunset Telephone Company, which has strung an experimental line, I believe somewhere out in this direction, were satisfied with aluminum and have begun to use the wire.

The question of price: It is considerably cheaper than copper. I don't know exactly what the price of copper is, but I think in the neighborhood of 21 cents today, and aluminum is in the neighborhood of 33 cents, and at these prices, taking into consideration the fact that you only have 48 per cent. of the weight of copper for a given conductivity, we can put up aluminum for a price that is about equivalent to copper at 16 cents per pound; so that there is a decided advantage in the matter of price in favor of aluminum.

For connecting aluminum wire we have a very simple joint which was invented, I believe, by Mr. A. M. Hunt of this city some years ago. It is merely a flattened aluminum tube, the two wires are laid side by side and twisted up in the same way the McIntyre joint is made. The McIntyre joint differs from the aluminum joint in that there are two tubes brazed together, but I presume at the time the McIntyre joint was devised the patentees were not familiar with the way in which a single tube would work. On the Standard company's circuit between Blue Lakes City and Stockton where the tubes were crimped before they were twisted, the tube falls right in between the two wires, and when a joint of this character is cut or sawn in two and the ends polished, it is very difficult to notice the line indicating the joint between the tube and the wire. Some tests made at the Pittsburg Reduction Company's factories show that after some of these joints had been immersed for over 36 hours in a strong alkali solution, they still had a higher conductivity than the wires themselves, so that, commercially, the joint is a good one

and eminently satisfactory. Some engineers were afraid moisture might get in and tend to impair the conductivity of the joints, and for that purpose have painted the ends of their joints with some elastic varnish, but it was as an additional safeguard, and I think practically the conditions of the aluminum joint are the same as the McIntyre joint.

DR. VAN NORDEN: What is the relative cost of stringing the wires?

MR. LEE: There is no reason why it should be more and a great many reasons why it should be less in cost than copper, because with the same conductivity you have less than half the weight to handle. There is every reason to suppose, if there is any difference, it is in favor of aluminum.

MR. MARTIN: As far as my experience is concerned, there is no difference in the cost of construction, as the linemen will not climb any more poles in a day, nor any less, and they will tie just as many wires.

MR. MASSON: We were told here some time ago about a man who went up a pole to string aluminum, and, speaking jocularly, found by his thermometer it was 72 and by his table found three spots on the red, or something like that, and then he pulled up the span. [Laughter.]

DR. PERRINE: I am afraid I am responsible for that I have always held, and I think in common with the engineers of the American Bell Telephone Company in the East, that all wire ought to be strung in accordance with the temperatures; and accordingly, when the Standard line was strung, I gave strict instructions to the men that they should tack to their wire wagon a thermometer, and that they should pay attention to a table of deflection, which was similar to a table of deflections I had prepared when we were intending to use copper, because I have seen many copper lines ruined by tight stringing without reference to temperature—particularly here in the West. Copper is just as devoid of elastic limit as aluminum, and if you string your copper in warm weather it is going to stretch in cold weather and you are going to have an increased length at an increased resistance. The Chicago-New York line was all strung with thermometers in the buttonholes of the linemen, and they do all of their good work in the East in that way. That is the whole origin of this thermometer business in connection with the Standard line. I would have used a thermometer whether it had been copper or aluminum. It is more necessary for this reason: You cannot find a lineman who has had the same amount of experience with aluminum as with copper. If I had a lineman who had strung as much aluminum wire as some telephone men have strung copper wire, I would consider that that man's judgment could be relied on. But consider our line: This line was No. 1 wire, and a No. 1 copper wire is very frequently strung with a team of horses on the ground. In this case, two men, or at most three men, on the ground could have over-strung the aluminum wire, and in stringing we had five linemen tying, two jointing, and four on the ground tackle.

PROF. CORY: Some tests on the aluminum wire used on the Blue Lakes-Stockton transmission line were made in the mechanical laboratory of the University of California recently, and it was shown there that the tensile strength of the wire was approximately 20,000 pounds per square inch. One test that was interesting was to determine the strength of the joints. One or two joints were tested, the joints having been made by the linemen on the Stockton line. It was found in every case that the wire itself was pulled in two before the joint gave way, showing that at least with joints very recently made, the strength is greater than that of the wire. Of course it should be remembered that this wire had not even been strung, so that it had not been subjected to any mechanical strain or continued vibration. Some tests were also made in the electrical laborotory upon the conductivity of the same wire, and the results in general agreed very closely with the tables of the aluminum company. Here again the joints made in the wire showed a less resistance than the main wire itself. What effect an alkali would have upon such joints of course could not be determined.

It is proposed, very soon, at the University, to make more careful tests upon aluminum wire, inasmuch as we will have one or two of such lines in operation within a short time. After these lines have been up for a few months, some more conclusive results will be obtained regarding the temperature coefficient and the effects of connections into copper or brass terminals. Even in the laboratory the remarkable lightness of the wire has shown its advantages, and but one difficulty was encountered in the tests we made, and that was, to handle the wire carefully.

Dr. Van Norden read a paper prepared by his son, Rudolph Van Norden, and reprinted on page 14 of the July number of the JOURNAL.

THE CHAIRMAN: I understand that Mr. Jones has had considerable experience in the paralleling of widely separated stations. May we hear from him?

MR. JONES: The Big Cottonwood station has a 2000-kilowatt equipment, and the Pioneer has practically 3000 kilowatts. They are 52 miles apart, have been running parallel for a year and a half I think, and no difficulty has been found in synchronizing and running the stations together except at the times line troubles occur when they are running in synchronism. The first application was at the time that the Cottonwood station had been in operation for about four months continuously without opportunity for cleaning up, and during one Sunday afternoon the Pioneer company took the load and permitted the Big Cottonwood plant to shut down. There had been a difficulty anticipated in synchronizing, and during the shut-down the station attendants changed the leads coming in from, I might say, the primary side of the Big Cottonwood, and started up the three generators, synchronized them together with the main line, and then synchronized that station with the Pioneer and the city station. The Pioneer did not know this was going to occur at all, there had been such a difference of opinion about it; they had a reckless man and he took it on his own hands to do it. After that the synchronizing was done, I think at all times at that station, instead of at the central point, Queen City. There has been no difficulty in that line whatever.

Mr. John Martin then read a paper on "Electric Lighting versus Gas," and reprinted on page 11 of the July number of the JOURNAL.

DR. VAN NORDEN: I don't think sufficient emphasis has been put upon the deterioration of the atmosphere in the room in the use of Welsbach burners. My attention was called to this when I went to Sacramento, and I was told this defect would prevent the success of that burner in that city. The mantel is composed of a substance which in the very great heat volatilizes and is poisonous, and as the burner requires not only oxygen, but a very large portion of air in the room in addition, which is mingled with the gas, so there is a double consumption of the air in the room—a double production of carbon bioxide. The effect upon a room with the windows and doors closed is extremely vitiating, far more so than with ordinary gas-jets. It is impossible for persons to use those burners with closed doors and windows and preserve health; and while persons using them do not discover it at once they find they do not enjoy life. I think the reason they have that feeling is largely that there is an effect upon them of which they become in time not exactly conscious, but sub-conscious. They know there is something wrong about that burner, and we find as a matter of fact that nearly all the Welsbach burners in Sacramento have been given up. I think in the long run they are sure to be thrown out universally as disagreeable, and the light they give, though undoubtedly economical, is extremely dangerous to health.

We have found from our experience that extravagance in

the use of lights on the flat rates lessens. At first the family revels in the light and all the burners are turned on, but after awhile they turn them off very much as they do gas; they don't care for the glare. With regard to the rates, we find that the average rate in Sacramento is for residences about 19 cents per month—a little less than that; that the average for business places, saloons, etc., is probably not over 40 cents, and yet it is a good business—at least our company has found it so. There is a very extensive consumption of the electric current because of the low rates, and it seems there is no limit to the business. I know when the Folsom company went into Sacramento their expectation was that a few thousand lights might be taken; I think we have very nearly 40,000 now in the city, and I see no reason why we should not have 80,000. I am quite confident another thousand horsepower will be put in Sacramento just on the incandescent lights. There is a large field for the use of gas in the heating of stoves and so on, and perhaps in some cases in gas engines; but gas as an illuminant is not to be feared—at least if we can do business on the rate we have in Sacramento.

MR. MARTIN: Being interested in a gas company, I tried to make my paper as unbiased as possible, because I have attended the meetings of the Pacific Coast Gas Association and also the Transmission Association, and I find the personnel of each association carried away with the idea that they were the only people on earth. Now, with all due respect to Dr. Van Norden, you will find, in competition with gas a gas plant administered on pure business lines and also progressive and active, that they will have a fair clientage for the use of gas for illumination, and largely for the purposes of heating. There are some people who object to the flickering of electric light, which happens occasionally with machines. There are some people who object to the white incandescence of the ordinary incandescent lamp, preferring the soft yellow light from a gas tip. They appreciate that in sitting in a room for a number of hours the air becomes vitiated; at the same time they are willing to put up with that for the other conveniences they receive. But that which appeals to most people is their pocketbook. After you get them in the habit of using one kind of illuminant they will not change it unless they are influenced by the price. The prices cited by Dr. Van Norden are much lower than the prices cited in my paper which were taken as an average of the prices in California. I assume 25 cents for residences and 80 cents for business houses, which is just a little under the average charge by the water power plants in California. Our experience in Grass Valley and Nevada City where we have been operating three and a half years, is such that the illumination of those two towns has increased almost 700 per cent.; that is, the amount of the candlepower illumination is over 700 per cent. greater than it was four years ago. We know that because we acquired the interests of the existing companies at that time, and our increase in total output has been 700 per cent. At my own house we have both gas and electricity, and without any education on my part I find that my electric bills are much larger than my gas bills, the gas being used almost entirely for heating and is very seldom burned for illuminating purposes.

MR. BEALE: The company of which I have the management for the time being sells its current at wholesale, and the gas company is going out of business as a gas company. One thing that has not been touched on, and which comes into very marked notice when you think of it a little, is the climatic condition in San Francisco. I would not be surprised at all at many people continuing the use of gas in San Francisco for the reason that the lighting of the gas in the chill hours of the evening does raise the temperature of the room. That would not be an advantage in Bakersfield or Sacramento. I don't think that anything ought to be sold at a flat rate, no matter whether it is gas or potatoes, or anything. I think the whole system is wrong. Give a man a fair measure for a fair price is the only really sensible way of selling anything, according to my standpoint, no matter what it is.

PCE. PONIATOWSKI: What has the public to say about that? Do they like flat rates or measurement?

MR. MARTIN: I presume that question is for me. I will make a homely illustration and let the managers understand why I favor flat rates. I will first give it from the consumer's standpoint, and then from the standpoint of the manager of a plant. The consumer analyzes your question about as follows: Having been consuming gas, which is a comparatively known quantity to him, (and forgetting that he in the past has complained about the excessive gas bills which he could not understand) you approach him for business, and the only way you can appeal to him—particularly in a small city—is to ask him how many lights he will average throughout the year, how many incandescent lamps will take its place, and at the rates which we have established in this community will the cost of it be greater or less, and in so determining take the total of his last twelve months' gas bill. They usually find that while in the summer time their gas bill may be a dollar and a half or two dollars per month for a small family, it will range from eight to twelve dollars per month in winter; whereas with the incandescent illumination at 25 cents per lamp per month he installs seven, ten or twelve lamps in his house, it will amount to $2.50 or $3.00 per month. He becomes favored with the idea and installs eight or ten lights; he visits his neighbor, who has twenty lights in his house and the house is well lighted; he goes home to his place and finds only one burner in the room, and finds it rather dark and gloomy; he thinks the matter over and, as a result, he puts in four or five lights more. That has been our experience in small towns. Now, from the standpoint of the manager of the plant: The average water power plant in this State is in search of business on the basis of horsepower. If we can obtain 75 or 80 per cent. of the price we are willing to sell our power for for 24 hours' service, and always have it available for at least twelve hours to dispose of, it certainly becomes a good financial business proposition.

There is one difference between this and and other lines of business, namely: your fixed charges are constant, assuming your installation to be based on a continual supply of water; you install 1000 or 1500 or more horsepower; your employees and your station operating expenses are constant at all times; the only additional expense on account of increased business would be the running of a few additional lines, a few more poles, and a few more transformers, which is a very small percentage of the total investment. Now, until you reach a point where the earnings of the plant are able to pay your fixed charges, you are always suffering a loss; but immediately you pass that line 95 per cent. of your earnings are a a profit. To that extent it differs from any other business I know of. Those are the reasons I maintain a sale of lights on flat rates are a benefit to the consumer, because he can use the light as he pleases without anxiety as to extra cost, and it is no detriment to the company because it is realizing an extremely good price per horsepower for its current.

PROF. CORY: I cannot take the side of either Mr. Beale or Mr. Martin on flat rates, because I have had no direct interest in any company furnishing lights; but I can say this: The University of California has a plant which supplies, I believe, fourteen different departments with electric energy. During the day the energy is used in the different buildings by many different people; and at night the energy is used almost entirely in lighting the library. We found, however, that the University people were very careless in going away from the buildings and leaving the switches closed, with the result that the electrical energy was wasted during the night in rheostats, lamps, etc., and we would have perhaps five horsepower going to waste in this manner from six o'clock

in the evening until 1:30 in the morning. That was a serious matter, from the coal-bill standpoint; so we decided, about a year ago, to put in meters in the various departments. Of course, no one individual is financially responsible, but the department budgets *are* responsible: and we found from the first that we were saving something like $35 a month on account of the meters. The total cost of these did not exceed $300. This led me to believe that what Mr. Beale has said is true: that a just, fair measure and a fair return is what ought reasonably to be expected on each side.

There is another point in connection with the flat rate versus the meter rate, and that is the incandescent lamp. There are incandescent lamps and *incandescent lamps*. Some lamps are very efficient with comparatively very short life; and other lamps are perhaps not so efficient and are longer-lived. In connection with the lighting of the University library—we use about 500 lights of 16 candlepower each—we find we are saving about $150 a year by using 3.1-watt lamps rather than 3.6-watt lamps. In other words, from our standpoint it is cheaper to burn up lamps than to burn coal. I do not think we would know about those things if it were not for the meters.

THE CHAIRMAN: Mr. Heger, will you give us your experience?

MR. HEGER: I have little or no experience on that subject, but I was interested in small stations in early days before meters were used to any great extent, and found out then that people wanted a very inefficient light that would last forever, and we found that would cut into our coal bill in such a manner that we concluded to furnish consumers with high efficiency lamps in order to keep the lamps at their actual efficiency all the time instead of letting them burn lamps that would last forever at our expense.

THE CHAIRMAN: What bearing will that have on the present construction of lamps? Has there been any modification of construction by which that is avoided?

MR. HEGER: I think it is conceded all around that it is better to use a higher efficiency lamp.

PROF. CORY: Not with a meter rate. If I owned an electric lighting station and was selling energy at so much per kilowatt-hour, I would want my customers to burn just as inefficient lamps as I could get them to use.

MR. HEGER: But you would lose your customers very quickly.

PROF. CORY: The trouble is, the customers don't know these things.

MR. MASSON: In considering this subject you cannot escape the source of power. If you are considering the question you have to consider where you get your power. As I understand Mr. Martin's idea, if you have a meter proposition and a water power plant on which a lot of miscellaneous customers are working, it is very well known that between seven and eight o'clock in the evening, if it is dark, (or between eight and nine) everybody is going to have his lights on, and that the peak of that plant will be a certain definite amount no matter whether you have a meter rate or a flat rate. Some people may turn off some of their lights, but taking a certain peak load, you can get more money from a man if you will let him continue to burn his lamps all night than you can if he can only burn them for one hour when he uses the meter. If the peak is the important feature and you allow him to continue the use of that lamp all night he will give you more money, and if you can get more money per kilowatt peak load by letting him burn his lamps all night and all day, I think that would be the best way to sell it. On a steam plant you don't care much what the peak is as long as you can keep down the total coal bill, and keep inside the plant capacity; so that whenever a plant is based on a supply of fuel or a supply of water that can be saved over until the next day, the meter is the right thing; but in all plants where the flow of water is not important except as a peak, the flat rate seems to be the best thing.

MR. MARTIN: I would like to know what difference it makes to a plant operating 2000 horsepower at $5.00 per horsepower per month, with a revenue of $10,000, or receiving $10,000 for flat rates for lighting, assuming the fixed charges and operating expenses were the same? I cannot see the difference.

DR. PERRINE: It seems to me the difference lies in the fact Mr. Martin forgets that "electricity is in its infancy," [laughter] and the history of this whole meter business throughout the country has been that when the plants were installed all they cared to sell was up to their peak load, and after a few years they began to care to cover the territory. I have been to a great many meetings of the National Electric Light Association, and I was there particularly when the plants were changing from flat rates to meter rates, and I found a strong argument in favor of the meters was that a certain original investment would handle a larger territory with meters than without meters, and that is the point which Mr. Martin neglects. It is not solely how large is your peak load and, consequently, how many dollars you are getting from it, but it is also how large a territory you are handling and how many customers you serve. So long as your water power is greatly in excess of the demands of the territory, perhaps the condition Mr. Martin speaks of is true, but inside of five years from now the probabilities are that a great many plants in California which now have water power to waste and are unloaded, will be fully loaded and hunting for more water power.

MR. BEALE: A thing to be desired is a load as near a hundred per cent. of the installatien as you can get. If a water power plant should be so fortunate as to have a great big meter load during the day, carrying it up to say, 66⅔ per cent. of its peak limit for an average load during the light hours of the day, there might be considerable force in the position Mr. Martin takes. I don't know of any such plant. I was talking on this subject just a day or two ago with Mr. A. M. Hunt, who has been making considerable research in this direction recently, and he tells me he has communications that indicate to him that the 24-hour average load some of the London plants run for lighting alone is a little over ten per cent. of the peak limit. Of course those are not water power plants. If these same plants had a good large stationary meter load you can readily see what the effect would be upon the installation, and a very short calculation would show you what your horsepower installed would be as compared with you horsepower revenue on a 24-hour basis. There is no question that after a while the people get over their playful extravagance when the door is thrown wide open to them, just as children will dive in when the pantry is open; but when left open for a month they get over it, and the extravagance will drop and they will not use current even on a flat rate to so large an extent as they would at first when having the opportunity of doing so. But the real point is, the giving of a definite thing out for a definite sum received. The customer who buys largely is entitled to a wholesale rate, but he is not entitled to any more units at the rate you give him than the man who buys a small quantity. The proper thing is, a yard of goods is bought for a shilling, and if you sell 1000 yards perhaps you can give a better rate.

The whole matter of flat rates has grown out of the proposition of introducing it into houses equipped for gas and not equipped for electricity. In some places the opposition lighting companies have begged the privilege of wiring the houses for nothing. We know that is ridiculous. We ought to give a better and cheaper service than the gas company can give—if we can—but in justice to our own interest it is the duty of every plant, of every institution organized as gas and electric light companies are, and as all quasi-public corporations are, to give to the community the cheapest ser-

vice they can, based upon the amount of capital invested. There are none of us who would care to sell anything we have other than electricity, at a flat rate. I have not any data on this except that which was brought to me by a customer who buys his electricity at a wholesale rate and sells it flat. I know his experience is foreign and radically opposed to what I consider a primary business principle; namely, a reasonable exchange of quantities.

THE CHAIRMAN: Then the installation of storage batteries would be an important factor in your manner of doing business—charging by meter rate?

MR. BEALE: Not so much so as in a flat rate. I have had no experience with storage batteries, and we are so situated that storage batteries do not cut much figure to us. We are in the situation that Mr. Martin is: we have more power than we have market for, and when the peak load comes on we simply pick it up and carry it and still have a margin left. We notice very markedly the difference between the peak load when the light comes on and the steady meter load which we have for twenty-four hours, and it is easy to see if the ratio between the meter load running through the day time and the peak load at night keeps on increasing, we must supply it away above our meter demands. Of course, all plants have to be over-installed, beside having spare units. They must have ability to reach exceptional peaks in the lighting business, such as demands made at Christmas and so on, but the ratio should not be too great; if it is, then you have too great a cost per unit of installation for your average load. When you have got that you have overburdened your plant with charges.

MR. HEGER: Are we not in the same condition as water companies supplying water through the eastern cities? Nearly all of them have kept their plants about the same and have increased their efficiency by introducing meters. I think that is true of nearly every water company in the larger cities, and electric lighting, while "in its infancy," is a pretty sturdy infant. Still, we are younger than the water companies, and could follow their example to advantage.

MR. MARTIN: The statement is quite true, but it is not a "deadly parallel." Our "coal bills" of water-driven plants are constant. Impress that on your mind and the other is easy to understand. In the case of the water supply companies this is not so.

MR. GILBERT: I think the gist of the whole subject lies in the difference in the way the power is furnished. Where power is in excess of demand the flat rate is the best. With a limited power I think there is no question that the meter is the only salvation for the plant, and I think the whole discussion really turns on the different classes of plant which are involved. I think the flat rate originated in a desire to get business in a way meter rates would not secure. In the early days of electric lighting when the coal bill was a large factor, we very soon found that the flat rate was a ruinous method of doing business; the difficulty was solved by selling current on the meter basis only. In summing up, I think with unlimited water power already installed and paid for, the flat rate would secure the earliest business, but I think the meter rate would have to be ultimately adopted to secure the best results.

DR. VAN NORDEN: I think we have all come to the conclusion in Sacramento that, for the present, the flat rate is best for us, while ultimately, when we get to the limit of our power, the meter rate will be quite necessary; but at the present time I think it is wise for us to adopt the flat rate as I think flat rates are getting us as large an amount of money for the horsepower as we could get if we sold it by the kilowatt-hour. Still, the time may come when we will lack power, and then we will undoubtedly adopt the meter system.

MR. MASSON: The fact a man requires an overcoat in winter does not show he needs one in summer. The Doctor wants a meter some day, but that does not show he wants one now.

THE CHAIRMAN: As the hour has arrived for the full members to go into executive session, the meeting will now stand adjourned until 8:30 p. m.

EVENING SESSION.

The convention reconvened at the appointed hour after dinner, President Pierce occupying the chair.

THE PRESIDENT: Our programme provides that at this time there will be informal discussions. Has any member any subject that he would like to bring before the meeting and have it discussed?

DR. PERRINE: I would like to ask expressions of opinion on the part of some of these practical men on the value of pins, cross-arms, and poles as regards insulation. Dr. Van Norden, in the paper by his son, read this afternoon, told of the value of treating pins with paraffine, and Mr. Martin and myself have had some discussion as to whether we could continue that insulation along the arms. Then the question came up, if you did that to the arms and neglected the poles, how far should the poles be treated. I have considered the matter very carefully, and have boiled our pins for about eight hours in an asphalum-tar mixture, and in lieu of something better that could be done immediately, I have creosoted our arms. Then the arms were put on a single bolt and braced with an iron brace. On later consideration it seemed to me that it was a mistake to insulate the cross-arms and then short circuit them with iron braces; so I talked the matter over with a mill man in Stockton and he suggested a wood brace, and sent me down a sample of arm braced with a wood brace, the arm having a mortise cut for holding the brace. One by two-inch braces were to be cut by a machine to an exact mitre and the whole construction seems very simple. I have presented this to a number of men and all the electrical men have said that a 2 x 1-inch wood brace would split. I have also presented this objection to all the mill men that I have been able to meet and they say that that is nonsense. They say a wood brace of that kind will stand perfectly well, as we have an example in fence pickets of about the same size, which last and which do not split. Then comes in the question of how far it is advisable to brace at all. The experiments that were made by the long-distance Bell Telephone Company show there is a decided advantage in boring one pole through cross-arms. Mr. Martin has bored one pole through cross-arms and has cut an inch deep in the pole, thereby making his cross-arm stand up all right without a brace, but weakening his pole. I have in mind a man who uses blocks on the pole alongside the arm, taking the place of the gain and brace altogether; but it does seem to me in long arms, say from five to seven feet long, if you use a single bolt and do not weaken the pole too much, not cutting more than half of three-quarters of an inch gain in a round pole, that the arms will require some bracing; and if you do brace the arm, and if you are going to have anything in the way of insulation in the arm, you must have a wood brace which is treated. The mill men here say that a treated redwood brace will stand all the strain necessary, will not split, and will accomplish the object to be desired.

Now, there are a number of questions that come in there:

First. How is the best way to treat the pins, if you treat them at all?

Second. How is the best way to treat the arms, if you treat them at all?

Third. How is the best way to bolt the arms, whether with one or two bolts, and if we bolt them with one bolt, what is the limit in length of arm that is safe not to brace if you do not cut more than three-quarters of an inch gain in the pole?

My own idea is if we do treat the arms and pins, they should be treated with something along the procedure used in creosoting. There have been experiments in creosoting

since long before the beginning of this century, in this and other countries, and all those experiments have apparently proved conclusively that creosoting is preservative and not a detriment only when the process thoroughly dries out the material. Then if you take ordinary timber—not green timber, but ordinarily dry timber—and creosote it or treat it in a couple of hours, that the timber will decay more readily than though it were not treated. Ordinarily, in arms we do not have to consider this decay. At the same time, if we do give any treatment at all, we have got to consider the question of decay, because if you do treat cross-arms and do not properly treat them, you will induce dry rot. So my impression is that we should treat pins and arms either by kiln drying or by cooking out in the treating process so thoroughly that we get rid of all moisture, and then penetrate as far as possible.

I started out with the original assumption that I would inject the arms and pins full of an insulating material, but after a long series of experiments, working with asphaltum and waxes up to 160 pounds pressure, I found it was practically impossible to inject a hardwood pin more than about one-sixteenth of an inch below the surface, and, in consequence, I have come to the conclusion that the best we can do is to thoroughly dry out pins and arms and give them a satisfactory coating. That coating I believe we can accomplish by kiln drying the lumber and then leaving it for from one to three hours in a mixture of asphaltum and drying oil. The ordinary pin insulating paint contains about 75 per cent. of bisulphide of carbon and 25 per cent. of asphaltum, and if arms which have been kiln dried are soaked in paint they become coated very thoroughly apparently with asphaltum, but as that asphaltum when it goes on contains 75 per cent. of bisulphide of carbon, it seems to me when it evaporates there is not much of insulation left. Accordingly I have come to the conclusion that our treatment can be better done with either pure asphaltum or an asphaltum coat with drying oil, or an asphaltum coat with turpentine, that will dry to a non-acid gum. I find you can get an asphaltum varnish made with turpentine at about 25 cents a gallon, whereas asphaltum made of linseed oils costs from 45 to 60 cents a gallon. The asphaltum varnish made with turpentine seems from the standpoint of the knowledge of the oil better than that made with linseed, because the linseed dries to an acid resin, and the turpentine dries to a non-acid resin.

Those are some of the points that have been troubling me directly, and I would like to hear if any of the men who have had experience in treating arms and pins and braces, and so forth, have anything to say, and also what are the ideas of persons who have not had any experience.

DR. VAN NORDEN: I would like to ask the professor whether he has had any practical experience on these lines, whether his theories have ever been put into practice in regard to the braces and the arms and the asphaltum and the pins. Are these theoretical considerations you have given us, or are they the result of experience?

DR. PERRINE: Not altogether. As regards insulating paints and the asphaltum coating I have had a good deal of experience with in insulating wires; and the common process of insulating wire is to pass a wire through a pot of hot asphaltum, braid on a cotton braiding, and then run it through an asphaltum pot again and polish it. That makes a very poor wire for the purchasing agents, because there are a lot of white threads in it. And, in looking around for something that would appeal to the engineer and purchasing agent both, I found that P. & B. paint gave an almost perfect saturation with a much cheaper process. All you have to do is to braid on a couple of braids of cotton on your wire without any soaking at all, and then run it through the P. & B. paint without any polishing, and it maks a perfectly soaked wire without a white thread in it.

DR. VAN NORDEN: I did not ask with reference to wires.

DR. PERRINE: The whole question of insulation must be treated together. The wire of which I speak sold well to the purchasing agents, but about the time that P. & B. paint came on the market, Leonard & Lizard of Chicago started testing the various water-proof wires. In every case a wire that had been insulated with an asphaltum coating that was made by a saturation solvent broke down before the insulations that were made simply with hot asphaltums and waxes. That is one practical consideration I have in regard to the treatment with something similar to asphaltum paint. What I ask for is some practical experience similar to that, and in regard to cross-arms.

DR. VAN NORDEN: It is that I want to give over against these theoretical considerations, which may be of great value for all I know. I can place our experience on a line of about thirty-five miles in all, and 16,000 volts. We fully believe, as the result of our experience, in the iron braces. We have been running for several years, and during all that time we never had our attention called to those braces as a source of weakness; never in any instance. We had an insulator on the top of our pole which was attached to the pole by means of an iron bolt, through to a V-shaped iron arrangement attached to the top of the pole by lag screws, and the current leaking through the insulator would work down the bolt into the V-shaped iron and thence through the lag screws into the heart of the wood, and we had difficulty with the upper pin so long as that wood had sap in it. As soon as the sap was entirely dried out it gave us no trouble. I believe it is a great deal better to have a shallow gain and to attach a couple of iron braces to the arm by means of lag screws.

With regard to the arms, we never had any burning of arms, or any trouble that resulted by reason of the fact the arms are not insulated. I don't think it is necessary to insulate the arms at all. So far af the pins are concerned I don't think a pin could possibly have been put to a better test than ours at this end of our line where the energy was 12,000 or 13,000, near Sacramento, where, as was stated in the paper written by my son, for a mile and a half we had ordinary glass telegraph insulators. These were very simple affairs indeed, and we watched them in every kind of weather. So far as any report has come to me, or any observation we have made, and we have looked into the thing pretty closely, no pin has ever been burned, no arm has been burned, and there has been no indication whatever of leakage. Judging from our experience with the larger insulators on pins that were not boiled in paraffine, we believe, if our pins had not been boiled in paraffine, that the experiment would have been a total failure. We do not believe the paraffine acts as an insulating material, and do not think on that account that the comparison with asphalt is of very much value. A good, dry pin is a good insulator itself, and the paraffine makes it impervious to water, absolutely so, so that the pin never gets damp and never becomes anything but an insulator, and never becomes a conductor. Our success with small insulators is owing to that fact, and we are quite confident we might replace all the large glass insulators and put on little ones all the way to Auburn without any damage whatever to our system, provided we first boiled the pins in paraffine.

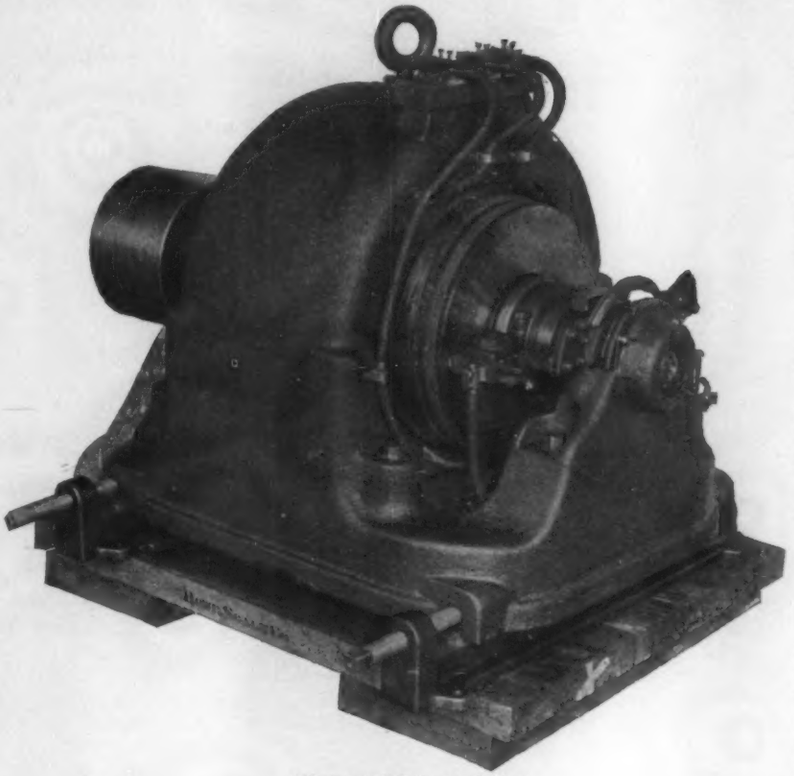
I regret I must disagree with the professor on all these three points, and I think back of my opinion is a very good and long experience. I think the arm should be supported by braces; I think the gain should be shallow; that the arm need not at all be insulated, and that you need do anything but cover it with some paint, say P. & B. paint—something of that sort—mainly to keep the wood from becoming soaked. That which does the work is the paraffined pin; I attach immense importance to that, and I believe we could reduce the expense of our insulators very largely indeed if we would use paraffined pins.

(Continuation in next number.)

Distribution

SINGLE-PHASE SELF-STARTING MOTORS.

SEVERAL different types of alternating-current motors have been described in these columns heretofore, and it is in order to similarly illustrate at the present time the latest form of single-phase self-starting motor—that of the Wagner Electric Manufacturing Company—that has made its appearance. This is well described in a paper read by W. A. Layman before the students of the Rose Polytechnic Institute,



THE WAGNER MOTOR.

from which the following is taken. In the preparation of the paper it was assumed that the greatest value would be derived by avoiding a discussion of the finer theoretical questions involved, thus confining the paper to practical aspects.

The incentive to produce a commercial single-phase motor has been very great since the earliest comprehension of the general properties of the alternating current, for the reason that practically this one element alone has been lacking to make the single phase system of current distribution the highest form of development in the field of central station practice. Many able investigators have devoted time and thought to it, but until a comparatively recent date scant reward in the way of a practical and durable form of motor has repaid their efforts.

Early efforts to produce such a motor were broadly confined to two characteristic types:

First. The synchronous motor.

Second. The direct-current motor especially constructed to operate on alternating currents.

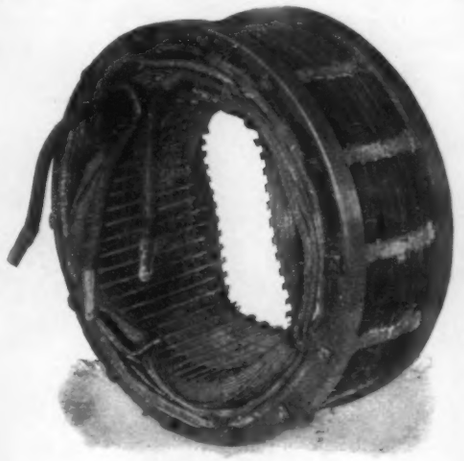
In the synchronous motor the fields are magnetized by a direct current, and the armature is supplied with alternating current corresponding in wave form and frequency to the current which the same machine would produce, at the same speed, operating as a dynamo. Two disadvantages arise, namely, *such a motor will not start from rest*, and, furthermore, to avoid fluctuations of the current necessary to operate with or without load, *the strength of the field must bear a definite relation to the load.* Such relationship is maintained with difficulty, and sometimes when the load is very irregular it cannot be maintained at all. When this arises the motor causes pressure fluctuations over the entire circuit from which it is supplied, practically crippling incandescent lighting from the same mains.

Many ingenious efforts have been made to overcome both difficulties, and not without a fair degree of success in one or two forms of motors. Two well known manufacturing companies have deemed their success such as to warrant them in putting single-phase synchronous motors upon the market. These companies were the Fort Wayne Electric Corporation and the Excelsior Electric Company. In the Fort Wayne motor no attempt was made to overcome the line pressure fluctuations with variable loads, and the designer's ingenuity was entirely confined to developing a satisfactory starting device, and providing for the self-excitation of the motor after up to running speed.*

The motor built by the Excelsior Company, in so far as Mr. Layman's information goes, differs from the Fort Wayne motor in that it has one or two refinements lacking in the latter. The Excelsior Company has endeavored to accomplish an automatic regulation of the field strength to the needs of the motor by introducing a small series transformer in the armature supply circuit. The secondary current from this series transformer is rectified by means of a two-part commutator, and sent into a special field winding. The second field winding corresponds to and serves the function of the compound winding in a direct-current machine, and, it is claimed, accomplishes the object of steadying the armature current with some degree of practical success. The criticism on this motor is that it is complicated, having two commutators and a pair of collector rings, two field windings and two armature windings.

Just what degree of success these companies have met with in introducing motors for practical power purposes has not been authoritatively stated, but the synchronous motor has certainly found one field in which it serves at present an almost indispensable end. This is in its application as a rotary transformer to the derivation of direct currents from alternating. For this service it has generally been designed to operate on two and three phase circuits.

The second general type of single-phase motor attempted by early investigators, namely, the direct-current motor constructed



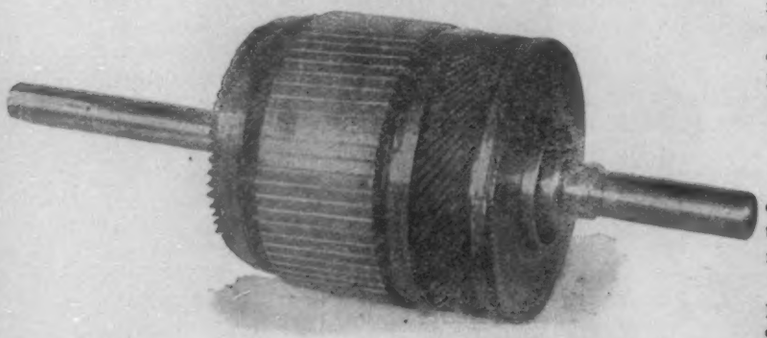
THE FIELD AFTER WINDING.

for alternating currents, has also run the gauntlet of innumerable efforts to make it practical, but has entirely disappeared for all

*See the illustrated description in the JOURNAL, Vol. V, page 131, Sept. 1897.

kinds of work except those involving very small amount of power. Aside from other disadvantages, this motor is barred from the field by the one consideration that electrical actions arise in the armature which make the destruction of the commutator by sparking very rapid. This feature of armature trouble is worthy of some discussion in detail. It arises from what may be termed a transformer action taking place in the machine.

All are familiar with the fundamental fact in alternating-current work, that a conductor introduced into an alternating magnetic field will have induced in it alternating currents, conforming in periodicity with the periodicity of this field, application of which



A SINGLE-PHASE MOTOR ARMATURE.

is made in the familiar static transformer wherein a primary coil is wound upon an iron core and a secondary coil also wound upon the core, has alternating currents generated in it by induction when an alternating current is supplied to the primary coil. Exactly the same thing takes place in the armature of the direct-current motor when it is attempted to operate it upon alternating currents. The effect of this action may be seen in Figure 1.

The coil *C*, which is a portion of the armature winding, is in the position, when by its rotation alone it is generating no electrical pressure, and therefore supplying no counter electromotive force. In the direct-current motor this wire is practically dead at this

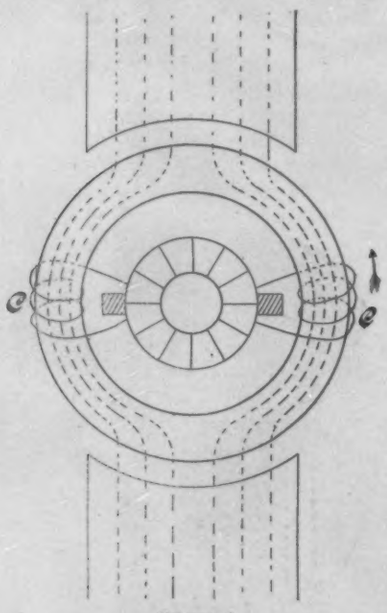


FIGURE 1.

instant. With an alternating magnetism, however, the coil is in the position to act as the secondary of a transformer, and since it is short-circuited by the brush bearing upon the commutator, it is evident that a heavy current will flow through it. When this short circuit is broken by the brush passing on to the succeeding segments of the commutator, heavy sparking results. This sparking is such as to make continuous operation in this manner altogether impracticable.

The single-phase alternating-current motor, therefore, in so far as these two types of construction go, has proven to be largely a practical failure, and it has only been in recent years, since the discovery of the principle of operation of the induction motor, that there has been offered to investigators any promise of success in this field of development. Since the introduction of the induction motor, several avenues of promised success in single-phase work have been opened up. In all, however, the fundamental element of success is the proper application of the induction motor principle.

The induction motor is nothing more nor less, from one point of view, than a special form of the alternating-current transformer. It consists of three elements:

1. A primary circuit or field.
2. An iron magnetic circuit.
3. A secondary circuit or armature.

In other words, it is a form of motor construction in which the outside supply circuit feeds the field windings only. By its function as a transformer, the motor generates for itself armature currents, which currents, under proper control, set up rotation.

Its earliest exemplification was in a type of construction probably designed to run upon the same general principle as direct-current motors. This was the motor devised by Messrs. Anthony, Jackson and Ryan, illustrated in Figure 2. Here the armature still is of the same construction in all details as the ordinary direct-current motor, wherein the brushes bearing on the commutator are connected to a locally closed circuit in which is introduced resistance, the amount of which may be varied at will. In operation, an alternating current sent into the field produces

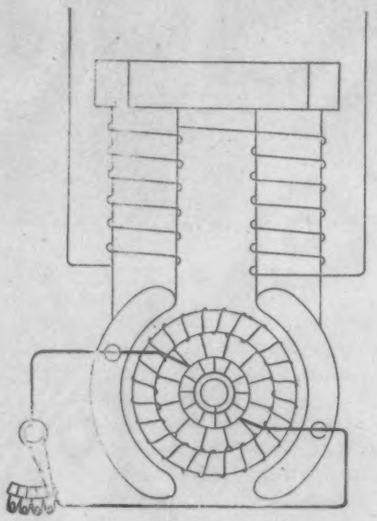


FIGURE 2.

by induction alternating currents in the armature, and these armature currents are commutated to produce rotation. Notwithstanding this great advance, commutator sparking still existed, and although this motor was brought out as early as 1887 nothing has ever been done with it commercially, except in a special use, as will be hereafter described.

The Anthony, Jackson and Ryan motor, although operating purely upon the induction principle, was not what is generally known today as the induction motor. Tesla found that commercial results could be secured if currents of two or three phases were used to produce a so-called rotating magnetic field; or, in other words, the effect of a strong magnetic pole revolving around the surface of a short-circuited armature. In a form of motor such as Figure 3, he would wind what would ordinarily be a twelve-pole machine in such a manner as to give him three sets of four poles. Into each set he would introduce one phase of a three-phase current supply. The poles produced by one phase, or

for example, *A A A A* would be immediately succeeded in point of time by poles produced in *B B B B* by the next phase of current, and so on around the periphery of the field, thus shifting the pole from *A* to *B*, *B* to *C*, etc. With such a field winding, it was found well to use a form of armature such as is illustrated in Figure 4. In this armature the winding of copper conductors consists simply of a large number of bars completely short-circuited at both ends, with respect to each other, by a copper ring. The resemblance of this form of winding to an old-style squirrel wheel gave rise to the popular name of a squirrel-cage winding. Such an armature, placed in a rotating magnetic field, will start from rest with a great deal of torque, and will quickly run up to a speed slightly less than the number of alternations of the current supply, divided by the number of poles of the winding. However, such a motor supplied with single-phase currents will not start from rest, and therefore, up to this point, the induction motor is not practicable for single-phase circuits. This arises

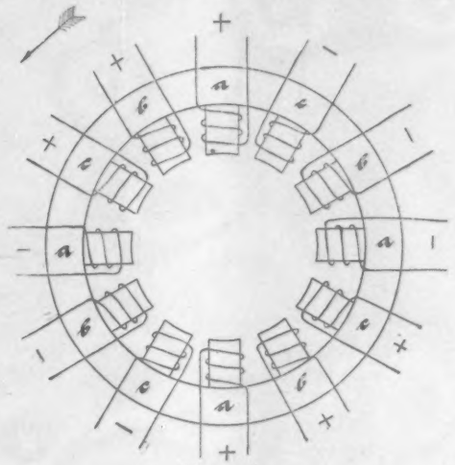


FIGURE 3.

from the consideration that a single-phase current will not produce a rotary field *while the armature is at rest*. The currents generated by induction in the armature conductors when the armature is standing still, select such paths of flow as to produce no resultant turning couple, with reference to a stationary field pole. Some of the currents tend to produce rotation in one direction, others in the opposite direction. They nullify each other in so far as the turning moment goes. In the two and three phase motors a different condition exists. The currents produced in the armature by any one set of poles bear the right relation to the poles of the next phase to afford an effective turning couple, and therefore the multi-phase motors are very effective in starting from rest.

When up to running speed, however, a motor constructed for a single-phase supply, *with armature corresponding to that of multi-phase motors*, will run in all respects practically as well as a two or three phase motor. In other words, the disadvantage of the induction motor operating on a single phase, as compared with two or more phases, is that the motor will not start from rest, but requires some auxiliary device for starting.

In the development of starting devices, several types of motors have been produced, and these may be spoken of in general as *modern single-phase motors*, thus distinguishing them from the motors previously described. These motors have taken two forms:

First. Those in which two and three phase currents are produced *artificially* from single-phase current, for the purpose of creating a rotating magnetic field in starting.

Second. Those falling back on the principles of the direct-current motor for starting.

In the first class might be placed all of the two and three phase motors of today, where the construction is such that the entire field winding can be fed either from single phase or polyphase without changing the number of poles. In other words, a standard two-phase or three-phase motor could, if properly connected, be fed from a single-phase circuit and operated on single-phase currents, *after having attained running speed*. But for starting, various devices are resorted to for phase splitting, as it is termed, to artificially produce two and three phase starting currents. Some of these devices are fairly satisfactory. The fault with all is that a very large amount of energy is taken from the supply circuit to produce differences of phase which are *variable* from low speeds up to full speed, and which, furthermore, do not provide a large amount of torque.

The second type of motor has been brought out by the Wagner Electric Manufacturing Company of St. Louis. Broadly speaking, it may be said that this motor starts according to the method first used by Messrs. Anthony, Jackson and Ryan, and illustrated in Figure 2. After getting up to running speed, connections are automatically changed so as to transform the motor into an induction motor pure and simple. This is accomplished by a complete short-circuiting of the commutator at running speed.

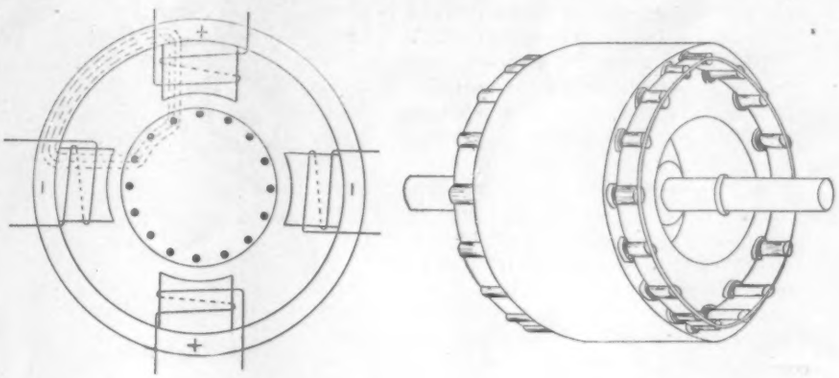


FIGURE 4.

In mechanical construction, this motor is, in many respects, very similar to that of the two and three phase motors upon the market. A field is built up of iron plates very much like *A* of Figure 5, and an armature core is also built up from iron plates very much like *B*. The field is wound with so-called pancake coils threading through the slots of the punchings, as shown at *C*, thus producing a magnetic pole of intensity, varying from a maximum along the radius *X Y* to zero along the radius *X Z*. The armature core is wound with an ordinary direct-current progressive winding, connected up to a commutator in exactly the same fashion as is the direct-current motor winding. The com-

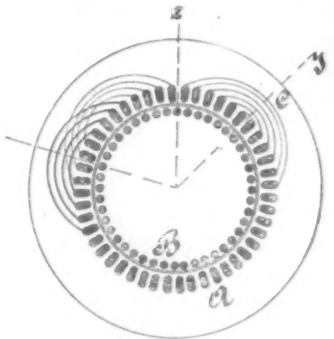


FIGURE 5.

mutator of this armature is so designed that it may be completely short-circuited by introducing into it a short-circuiting circle of copper segments. When so short-circuited, the winding affords a substitute for the squirrel-cage form of winding, but differing therefrom in that instead of currents being able to select paths for themselves, they are restricted to flowing in paths afforded by the individual coils.

The operation of this motor is based wholly upon the principle that an induction motor with a completely short-circuited armature will, when up to the running speed, operate on single-phase current supply in exactly the same manner as does a two or three phase motor with two or three phase current supply. Therefore, after the advent of the rotary field induction motor, the problem to be met in developing a successful single-phase motor was the provision of a starting device which would afford ample starting torque at all speeds between rest and running speed, without excessive consumption of current, and of a mechanical construction equally durable with the rest of the motor. In doing this there has been brought out a line of small motors claimed to be equal to the best two and three phase motors.

As to its starting characteristics of torque and current, the Wagner motor is said to correspond closely with the series direct-current motor. The armature winding is, however, short-circuited through carbon brushes bearing upon the commutator surface, and the currents flowing in it are generated by induction from the field. These currents flow out through the carbon brushes either into an outside resistance box, or where a direct short circuit of the brushes is provided, out through one brush and back into the armature through the other. By the shifting of the brushes on the commutator surface, they are forced to take such position relative to the magnetic poles of the field, that repellant action between them and the poles of the fields is effected, and rotation results. In other words, the currents which would be ineffective in the induction armature at rest, are forced to take such positions that they become equally effective with the starting currents produced in the armatures of two and three phase motors. When running speed is attained, the brushes are no longer required and the armature winding is completely short-circuited, as stated. In the mechanical development of this form of motor, many novel features have been introduced. The commutator is of a radial, instead of the horizontal type. The short-circuiting ring is made up of small copper links, which links, being in turn mounted upon a short-circuiting band, are thrown into the annular opening in the commutator, and by making close contact with the individual segments produce a very effective short-circuiting of the entire armature winding. (Figure 6.) In the operation of the motor, it is very advantageous to have this short-circuiting operation performed either at or slighty below the running speed. To remove all uncertainty of this being done at the proper instant, these motors are built with an automatic device for performing this operation. This device consists of a set of governor weights acting against a spiral spring. The centrifugal action of the weight will, at the proper speed, force the short-circuiting links into the commutator, against the action of the spring. At the same instant and by the same means, the brushes bearing upon the commutator are thrown off.

The makers claim that these motors are so designed as to carry a large percentage of overload without any serious consequence, and that if this capacity for overload is exceeded, the motor will come to rest in exactly the same way as will a two or three phase motor under the same conditions. If the overload is temporary, however, the motor will, without attention, run back to speed, as in slowing down the brushes are automatically thrown back on the surface of the commutator, and the motor is again placed in a starting condition.

With this motor, as with any electric motor, the points to be considered in determining the excellence of design are:

1. Its starting torque.
2. Its starting current.
3. Its consumption of energy while running idle.
4. Its efficiency at all loads.
5. Its power factor.
6. Its drop in speed with load.

The starting torque of this form of motor can be made, by adjustment, large or small as desired; a feature certainly very desirable, since the consumption of current in starting is proportional, practically, to the torque. This adjustment of torque is accomplished by shifting the brushes upon the commutator surface. When the motors leave the factory, the brushes are set so as to just bring up full load. The relation of torque and current under this condition is shown in Figure 7.

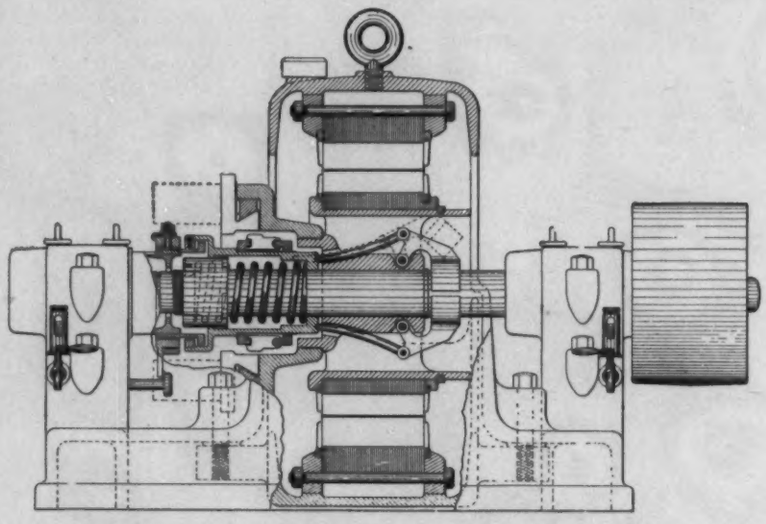


FIGURE 6.—CROSS SECTION OF WAGNER COMPANY'S MOTOR.

The energy required to operate the motor without load is very small, being practically the same as that required by direct-current motors. The efficiencies which have been secured in these motors are also practically identical with those secured in the best direct-current motors. The power factors are as high as those secured in two and three phase motors, and the drop in speed with load is very small indeed. In Figures 9 to 15 are shown the results of a test upon a five-horsepower sixty-cycle motor, made by students of the University of Nebraska, during the spring of 1898, under the direction of Prof. R. B. Owens. One set of tests there made

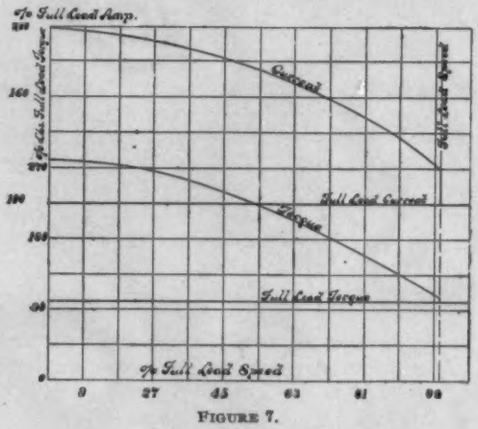


FIGURE 7.

was the measurement of the various electrical factors with different applied electrical pressures at the terminals of the motor. In other words, the motor as sent out by the builders was designed to operate on a pressure of 104 volts. Tests were made with a variation of this voltage in steps between 70 and 120. The effect of these various voltages upon the various factors are very nicely illustrated in Figures 9 to 11 inclusive. The judiciousness of the ratings given by the builders is very clearly brought out in these

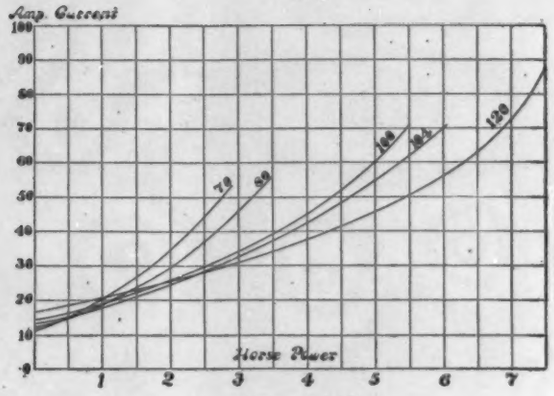


FIGURE 9.

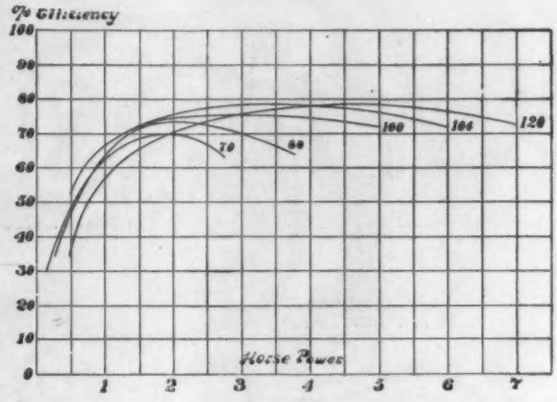


FIGURE 10.

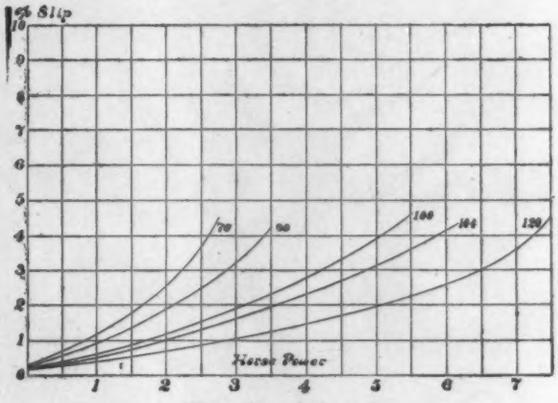


FIGURE 11.

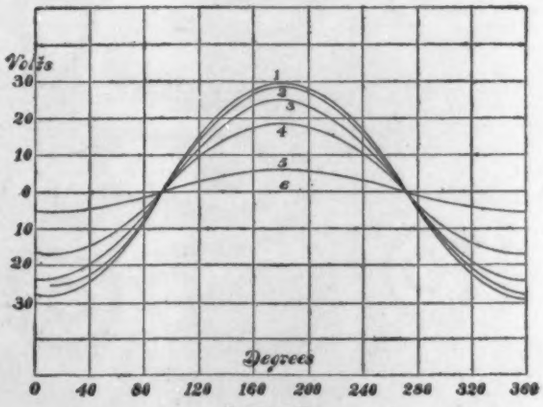


FIGURE 12.

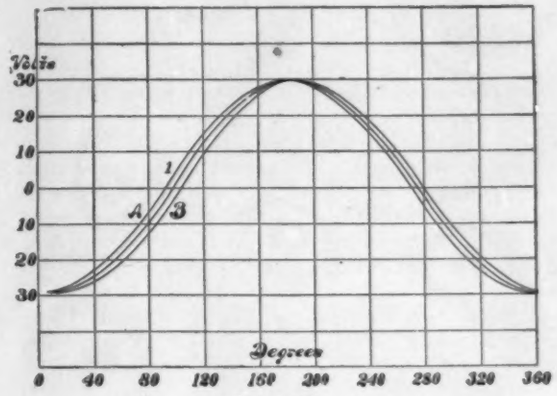


FIGURE 13.

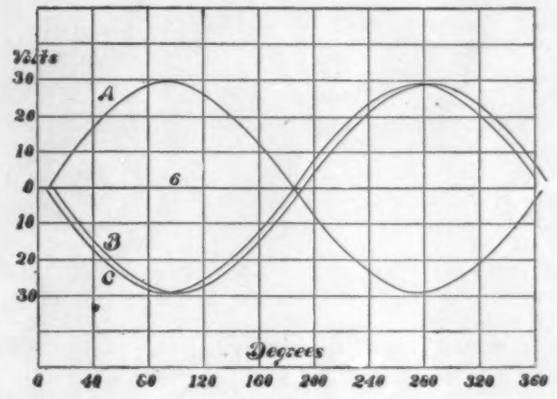


FIGURE 14.

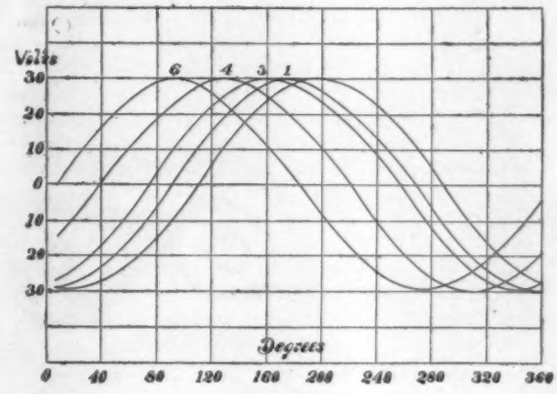


FIGURE 15.

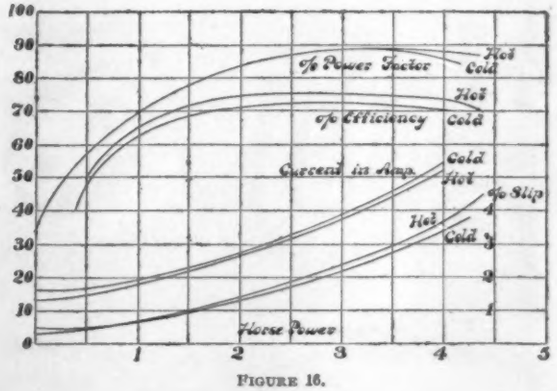


FIGURE 16.

curves. A particularly noticeable feature is the small percentage of slip at the rated capacity of the motor, namely, three per cent.

Another set of tests made at the University of Nebraska, was a determination of the exact magnetic actions going on in the motor. In other words, the students attempted to determine, under all conditions of load as well as when standing idle, the exact form of magnetic field produced by their single-phase sine wave current supply. For this purpose they introduced exploring coils in the slots of the field punchings. Each of these exploring coils embraced one-fourth of the slots of the entire field corresponding in that way to the exact breadth of the polar winding of the motor. These exploring coils were introduced progressively around the frame in such a way that the first one enclosed the entire winding of one pole, the next one $\frac{3}{4}$ of the winding of the first pole, and $\frac{1}{4}$ of the winding of the next pole; the third one enclosed $\frac{1}{2}$ of the winding of one pole, and $\frac{1}{2}$ of the winding of the next, etc., progressively until a point was reached where half of one pole and half of the next pole was enclosed. By the proper introduction of measuring apparatus they could tell just what the magnetic strength in the section of the field embraced by each coil was at any instant. Therefore, plotting these instantaneous results with respect to time, they could determine the exact form of wave and its net numerical value all around the interior surface of the field punchings. In Figure 12, the results of their tests are shown with the motor standing still. The result here is just what might have been expected, namely, that in this condition of affairs, the field is a pulsating one and decreases in magnitude at any instant as you progress around the circumferance from the central radius of each pole. In Figure 13 is shown the reactive effect of the armature upon the strength of the field immediately in the center of each pole winding, between the limits of no load, half load, and full load. The displacement seems to correspond in per cent. to the per cent. of slip. In Figure 14 are plotted the reactive effects on the magnetic field caused by the rotation and the current of the armature winding. A close study of these curves as compared with the curves of Figure 12, reveals the fact that the armature reactions of the motor when up to speed are such as to entirely change the character of the magnetic field, actually producing as perfect a rotating magnetic field as is created by a multiphase current supply. In Figure 15 is shown the reactive effect of the armature upon that portion of the field embraced in the exploring coil which gives a horizontal line in Figure 12. Here curve 6 shows that the resultant magnetism enclosed by this exploring coil is zero when the motor is at rest.

Curve *A* shows the condition of affairs with the motor running in one direction. Curve *B* gives the corresponding result with the motor running in the other direction. Curve *C* shows the displacement of *B*, due to load on the motor. These various magnetic curves are worthy of much closer study tnan can be given in the limits of this paper.

Another test made by the University students was to determine the effect of continuous load upon the motor. In other words, to compare the electrical conditions of the motor operating cold and hot. These results are shown in Figure 16, and disclose the fact that the motor is more efficient and operates with better results in every respect except slight increase in the percentage of slip, when hot than when cold.

In the winding of these motors, it is possible for the builders to secure a variety of results; for instance, where a large starting torque is required, an auxiliary connection can be made, the effect of which is to rate up the motor in capacity. The builders term this a loop connection, and for this connection provide a third terminal upon the terminal board. If the circuit is connected to this terminal and the common terminal for starting, 50 per cent., 75 per cent., and in extreme cases 100 per cent. overload may be brought up to running speed. When up to running speed connections are changed by means of a throw-over switch in the supply circuit, so that the current is supplied to the normal winding of the field.

The extreme simplicity of the motor arises from the fact that it can be connected upon the same circuit with incandescent lamps and operates thereon without any disadvantageous effects. Furthermore, operating on a low tension, there is no danger from accidental contact. If it is desired to operate on higher voltages, windings will be provided to correspond. The manufacturers have designed alternating-current motors of this character up to and including 20 horsepower capacity for 60 cycles, and 15 horsepower for 133 cycles. Larger sizes are to be brought out in the near future. The limit of adaptability of this motor to various kinds of power work is set by the frequency of starting necessary, as explained above. The motor can not be continuously operated upon the commutator, and in so long as the starting is of infrequent character, satisfactory results can be guaranteed. For ordinary running service, where starting but once or twice a day is necessary, the life of the commutator is indefinite.

Obituary

HERBERT H. BROOKS, late general manager of the American Circular Loom Company, died at his home in West Medford, Mass., on July 9th last. Mr. Brooks had been a sufferer from consumption for several years and had made trips to California, Mexico, the West Indies, and other points in the effort to restore his health, but all were without avail. He had been connected with the American Circular Loom Company since its inception, and had much to do with perfecting the well-known form of flexible conduit which his brother, now deceased, invented.

The death of Mr. Brooks recalls tender memories of the few days spent by the writer at the charming old homestead in West Medford, where for generations the Brooks family has lived. Interesting though the old home was, with its almost countless colonial treasures, this interest paled in the light of the beautifully tender affections thereever existing between mother and sons. Mrs. Sarah W. Brooks, now probably in the eighties, is all that intellectual refinement and ripened experience can make of noble womanhood — no ideal is higher — and one of her books, that on "English Poetry and Poets," is among the best reviews on English literature which has ever appeared. In her son, whose untimely death is now mourned, the electrical world recognized a man who courted and won success by unyielding fairness, who was so thoroughly good that he could not see evil in others, and who, above all else, attained an element of popularity that was closely akin to true affection. No one ever spoke ill of Herbert H. Brooks: no one could; but however high his memory may stand in the esteem of his fellow man, there is still a higher niche that it can occupy in the minds of those who knew his inner nature as revealed it. the beautiful tenderness of his home life. Mr. Brooks never married, but leaves a mother and brother who, though they feel the depths of grief, are among thousands who mourn his loss.

AUG. I. NEISSER, well known to the electrical interests of the West, and more especially in California, died in Los Angeles during the latter part of July. Mr. Neisser had long been a sufferer from consumption and some three years ago moved his place of business from San Francisco to Los Angeles that he might escape the rigors of the summer winds of the metropolis. This move undoubtedly prolonged his life, but the end was inevitable, even in the salubrious climate of southern California. He was best known as the Pacific Coast representative of the Central Electric Company of Chicago, and all, even to his keenest competitors, have always conceded to Mr. Neisser the credit of a fairness, thoroughness and earnestness in business that is exemplary. Personally, Mr. Neisser was a charming character, his whole energies being devoted to furthering the comfort and well-being of his parents, brothers and sisters. Although no information is at hand, yet is probably safe to say that his business will be conducted by his brother, Otto Neisser, who has for some months been in charge of the late Mr. Neisser's San Francisco office.